THE

GALLERY

OF

NATURE AND ART;

OR,

A TOUR THROUGH CREATION AND SCIENCE.

VOL. III.

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THE

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OF

NATURE AND ART;

OR,

A TOUR THROUGH CREATION AND SCIENCE.

BY THE REV. EDWARD POLEHAMPTON,

FELLOW OF KING'S COLLEGE, CAMBRIDGE;

Assisted by Distinguished Writers in the various Departments of the Work.

ILLUSTRATED WITH ONE HUNDRED PLATES,

FROM NEW DESIGNS, DESCRIPTIVE OF THE WONDERS OF NATURE AND ART.

BENEATH HIM, WITH NEW WONDER, NOW HE VIEWS,
IN NARROW ROOM, NATURE'S WHOLE WEALTH.

MILTON.

IN SIX VOLUMES.

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THE GALLERY OF NATURE AND ART.

PART I.
NATURE.

BOOK II.
GEOLOGY.
[CONTINUED.]

CHAPTER XXXI.

SPRINGS, RIVERS, CANALS, LAKES, CATARACTS, AND INUNDATIONS.

SECTION I.

Origin of Springs and Rivers.

THIS subject is still involved in a considerable degree of obscurity. The theories which have been chiefly invented to account for it are the three following:

I. The conveyance of the water of the ocean through subterraneous ducts or canals, to the place where the spring flows out of the earth, and the fountain on the river commences. Water, however, could never in this simple manner, by any power we are ac-

quainted with, rise to the surface of the loftiest mountains, where it is traced so abundantly. And to this hypothesis has consequently been added that of subterraneous heats or fires, by which, the water being rarefied, has been conceived to ascend through the bowels of the mountains in the form of vapours, and to be afterwards condensed, and once more rendered liquiescent. Yet no sufficient proof has hitherto been offered either of the existence of such subterraneous fires, or of such cavernous structure, in the mountains supposed to be operated upon.

II. The capillary hypothesis: or that of those who conceive that the water ascends from the depths of the sea through the sandy or other pores of the earth, in the same manner as it rises in capillary tubes, in sponge or sugar-loaf, so long as the latter remains undissolved. It is, however, sufficient to observe, in confutation of this hypothesis, that though, in consequence of capillary attraction, the water may reach the top or extremity of the hollow sand or minute tube, it will pass no further; it will neither rise above the surface of the mountain, so as to roll down its lateral surface in torrents, nor constitute cisterns or cavities, in such elevated situations.

III. The hypothesis of evaporation: or the origin of springs, and rivers from melted snow, rain, dew, and condensed aërial vapours.

But is the process of evaporation thus contemplated in the aggregate, equal to so prodigious an effect? and are those countries or places most remarkable for the number and extent of their rivers, when evaporation exists in the greatest abundance?

If we may credit Mr. Williams, the evaporation from the surface of land covered with trees and other vegetables is one-third greater than from the surface of water; but this has not been confirmed by other philosophers. From his experiments it appears that in Bradford in New England the evaporation during 1772 amounted to 42.65 inches. But from the way that his experiments were conducted, the amount was probably too great. From an experiment of Dr. Watson, made June 2, 1779, after a month's drought, it appears that the evaporation, from a square inch of a grass plat, amounted to 1.2 grains in an hour, or 28.8 in twenty-four hours, which is 0.061 of an inch. In another experiment, after there had been no rain for a week, the heat of the earth being 110°, the evaporation was found almost twice as great, or = 0.108 of an inch in the day:

the mean of which two experiments is 0.084 inches, amounting for the whole month of June to 2.62 inches. If we suppose this to bear the same proportion to the whole year, that the evaporation in Dr. Dobson's experiments for June do to the annual evaporation, we shall obtain an annual evaporation amounting to about 22 inches; which is much smaller than the average obtained by Mr. Williams.

Mr. Dalton and Mr. Hoyle have offered us experiments still more correctly conducted. They took place in the vicinity of Manchester during 1796, and the two succeeding years: and according to these experiments the quantity of vapour raised in that quarter annually is about 25 inches; and if to this we add five inches for the dew, it will make the average evaporation for the year 30 inches. Now if we consider the situation of England, and the greater quantity of vapour usually admitted to be raised from water, it will not surely be considered as too great an allowance if we estimate the mean annual evaporation over the whole surface of the globe at 35 inches. But 35 inches from every square inch on the superficies of the earth make 94.450 cubic miles, equal to the water annually evaporated over the whole globe.

This may be a quantity altogether sufficient for the formation and supply of those immense masses of water which constitute the largest of those rivers which we shall presently notice in their order. But by what means is this prodigious expanse of vapour converted into rain, in which form alone it can generate rivers, if it generate them at all?

Rain never begins to fall while the air is transparent: the invisible vapours first pass their maximum, and are changed into vesicular vapours; clouds are formed, and these clouds are gradually dissolved in rain. But clouds are not formed in all parts of the horizon at once; the formation begins at one particular spot, while the rest of the air remains clear as before: the first cloud rapidly increases till it overspreads the whole horizon, and the rain then commences. Now it is remarkable, that though the greatest quantity of vapour exists in the lower strata of the atmosphere, clouds never begin to form there, but always at some considerable height. It is remarkable too, that the part of atmosphere at which they form has not arrived at the point of extreme moisture, nor near

that point, even a moment before their formation. They are not formed then, because a greater quantity of vapour had reached the atmosphere than could remain there without passing its maximum. It is still more remarkable, that when the clouds are formed, the temperature of the spot in which they are formed is not always lowered, though this is sometimes the case. On the contrary, the heat of the clouds themselves is sometimes greater than that of the surrounding air. Neither then is the formation of clouds owing to the capacity of air for combining with moisture being lessened by cold: so far from this, indeed, we often see clouds which had remained in the atmosphere during the heat of the day disappear in the night after the heat of the air has diminished. And hence the formation of clouds and rain, from which rivers are so generally supposed to proceed, are themselves not to be accounted for upon any principles with which we are acquainted.

It is a very remarkable fact, that evaporation often goes on for a month together in hot weather without any rain. This occasionally occurs in our own country; and takes place every year in the torrid zone. Thus at Calcutta, during January 1785, it never rained at all: the mean of the thermometer for the whole month was 66½ degrees: there was no high wind, and indeed during great part of the month little wind at all. And this is also a fact that it is impossible for us to account for. The enquiry therefore is involved in great difficulty. In the beginning of the late century, the philosophical world was agitated by a variety of opinions upon the subject. One party contended strongly for the existence of a large mass of water within the bowels of the earth, which supplied not only the rivers but the ocean itself; at the head of these we may place the ingenious but fanciful Burnet. The French philosophers, on the contrary, asserted, that the waters of the ocean were conveyed back by some subterraneous passages to the land, and being filtrated in their passage, returned again to the sea in the course of the rivers; but this opinion appears contrary to all the known principle of hydrostatics.

It was in opposition to these hypotheses, that our illustrious countryman Halley contended for the process of evaporation, and maintained that the immense deposition of water in consequence of it, is fully adequate to the whole supply.

The experiment upon which he chiefly depended was the following. He took a vessel of water, made of the same degree of saltness as the sea, which he ascertained by an hydrometer; and having placed a thermometer in it, he brought it, by a chaffing-dish to the heat of the air in the hottest summer. He then placed this vessel, with the thermometer in it, in one scale, and nicely counterpoised it with weights in the other. After two hours, he found that about the sixtieth part of an inch had escaped in vapour, and consequently, in ten hours, the length of a natural day, that one tenth of an inch would have been evaporated. From this experiment it should follow that every ten square inches of the surface of the water yield a cubic inch of water in vapour per day, every square mile 6,914 tons, and every square degree (or 69 English miles) 33 millions of tons. Now if we suppose the Mediterranean to be 40 degrees long, and 4 broad at a medium, which is the least that can be supposed, its surface will be 160 square degrees, whence there will evaporate 3280 millions of tons per day in the summer time. The Mediterranean receives water from the nine following great rivers, the Iberus, the Rhine, the Tiber, the Po, the Danube, the Neister, the Boristhenes, the Tnais and the Nile; the other rivers that empty themselves into it being comparatively small, and their water inconsiderable. Now let us suppose that each of these rivers conveys ten times as much water to the sea as the Thames; which is calculated to yield daily 76,032,000 cubic feet, equal to 320 millions of tons, which is little more than one third of the quantity evaporated every day from the same sea: the remainder being perhaps allotted to rains, which fall again into different seas, after having served the purposes of vegetation. It is highly probable, however, that by some means or other, a kind of circulation is carried on through all nature; and that the sea receives back again, through the channel of the rivers, that water which it parts with to the atmosphere.

All rivers have their source either in mountains, or elevated lakes; and it is in their descent from these, that they acquire that velocity which maintains their future current. At first their course is generally rapid and headlong; but it is retarded in its journey by the continual friction against its banks, by the many obstacles it meets to divert its stream, and by the plane's generally becoming more level as it approaches towards the sea.

Rivers, as every body has seen, are always broadest at the mouth, and narrower towards their source. But what is less known, and probably more deserving curiosity, is, that they run in a more direct channel as they immediately leave their sources; and that their sinuosities and turnings become more numerous as they proceed. It is a certain sign among the savages of North America, that they are near the sea, when they find the rivers winding, and every now and then changing their direction. And this is even now become an indication to the Europeans themselves, in their journeys through those trackless forests. As those sinuosities, therefore, increase as the river approaches the sea, it is not to be wondered at, that they sometimes divide, and thus disembogue by different channels. The Danube disembogues into the Euxine by seven mouths; the Nile, by the same number; and the Wolga, by seventy.

There are some rivers which are said to lose themselves in chasms under the earth, and to flow for several miles in secret and undiscovered channels. On this circumstance is founded one of the most beautiful fables of antiquity, relative to the fountain of Arethusa, in Sicily. The same thing is affirmed of the Rhine, and even of the river Mole, in Surry, which from this circumstance derives its name. With respect to the two latter rivers, however, some doubts are entertained of the aserted fact.

On this subject there is a valuable article in the Memoirs lately published, by the abbé Guettard. "It is very surprising (he observes) if we reflect on it, that a river in its course, which is very often very extensive, should not meet with spongy soils to swallow up its waters, or gulphs in which they are lost; nevertheless, as there has been hitherto known but a small number of rivers whose waters thus disappear, this phenomenon has been accounted very extraordinary, both by the ancients and moderns. M. Guettard next describes what he has observed in several rivers of Normandy, which are lost and afterwards appear again; these are five in number, viz. the Rille, the Ithom, the Aure, the river of Sap André, and the Drôme. The three first disappear gradually, and then come in sight again; the fourth loses itself entirely by degrees, but afterwards re-appears; the fifth loses some of its water in its course, and ends by precipitating itself into a cavity, whence it is never seen to rise again.

What seems to occasion the loss of the Rille, the Ithon, and the

Aure, is the nature of the soil through which they pass. M. Guettard has observed that it in general porous, and composed of a thick sand, the grains of which are not well compacted together; it sinks suddenly down by its own weight in some places, and there forms great holes; and when the water overflows the meadows, it frequently makes many cavities in several parts of them. If we therefore suppose inequalities in the channels of these rivers, and that there are certain places in which the water stagnates longer than in others, it must there dilute the ground, if we may use that expression; and having carried away the parts which united the grains of sand together, those grains will become afterwards no other than a kind of sieve, through which the waters will filtrate themselves, provided nevertheless that they find a passage under-ground through which they may run. This conjecture appears to be so well founded, that each of these three rivers loses itself nearly in the same manner, that is, through cavities which the people of the country call betoirs, and which swallow up more or less according to their largeness. M. Guettard, who has carefully examined them, remarks, that these betoirs are holes in the form of a tunnel, whose diameter and aperture is at least two feet, and sometimes exceeds eleven; and whose depth varies in like manner from one and two feet, to five, six, and even twenty. The Rille during the summer season loses almost all its water in the space of two short leagues; the Ithon does very near the same. But M. Guettard observes something curious concerning this river, that formerly it was not lost, but kept its course without any interruption, as appears by the history of the country; very likely the mud, which had been collected together in several parts of its channel, might have occasioned the waters remaining in others, and have caused many betoirs. This is the more likely, as the mud having been collected together in the bed of the river Aure, it appears that, in consequence, the cavities were greatly increased, which makes it lose itself much sooner than formerly. Besides, possibly an earthquake happening in the country might have caused several subterraneous canals through which the water of the Ithon has forced its way. In effect, it appears, that a soil's being porous is not sufficient to cause the loss of a river; for if it was, then to do so it would occasion many fens round about, nor would it renew its course after having disappeared a certain time; it must

besides find ways under-ground through which it may take its course. M. Guettard seems also much inclined to believe, that there are, in these parts, subterraneous cavities through which the waters may flow; and in consequence of this he reports a number of facts, all tending to prove the truth of it, or at least to prove that there must be hollow quarries serving for strainers to these waters. Upon which occasion he goes into a discussion of this question; Are there any subterraneous rivers, and is the prepossession of some persons in favour of this particular well founded? He makes it appear by several instances which he quotes, and by many reasons which he alleges, that there are at least very great presumptions in favour of this opinion. We are too apt not to look beyond the exterior of things: we feel resistance upon the surface of the earth; when we go deep, we often find it it compact. It is therefore hard for us to imagine that it can contain subterraneous cavities sufficient to form channels for hidden rivers, or for any considerable body of water; in a word, that it can contain vast caverns; and yet every thing seems to indicate the contrary. A fact that is observed in the betoirs of the rivers concerning which we have spoken, and particularly of the Rille, proves in some measure that there are considerable lakes of waters in the mountains which limit its course; this fact is, that in winter the greatest part of their betoirs become springs, which supply anew the river's channel with as much water as they had absorbed from it during the summer. Now from whence can that water come, unless from the reservoirs or lakes that are inclosed in mountains, which being lower than the river in summer, absorb its waters, and being higher in winter by the rain they receive, send it back again in their turn?

M. Guettard strengthens this conjecture by several instances that render it very probable: he remarks at the same time, that this alternate effect of the betoirs swallowing up the water and restoring it again, causes perhaps an invincible obstacle to the restraining of the water within the channel of the river. It has indeed been several times attempted to stop those cavities; but the water returns with such violence in winter, that it generally carries away the materials with which they were stopped.

The river of Sap André is lost in part, as we have before said, in the same manner as the Ithon and the Rille; but there is something

more remarkable in it than in those rivers; to wit, that at the extremity of its course, where there is no perceptible cavity, it is ingulphed, but without any fall; the water passes between the pebbles, and it is impossible to force a stick into that place any further than into the betoirs of which we have spoken. What makes this river take that subterraneous direction, is an impediment which its stream meets with in that place; it is there stopped by a rising ground six or seven feet high, whose bottom it has very likely undermined, to gain a free passage, not having been able to make its way over it. At some distance it appears again; but in winter, as there is a greater quantity of water, it passes over that eminence, and keeps an uninterrupted course.

Lastly, the Drôme, after having lost some of its water in its course, vanishes entirely near the pit of Soucy; in that place it meets with a sort of subterraneous cavity near 25 feet wide, and more than 15 deep, where the river is in a manner stopped, and into which it enters, though without any perceptible motion, and never appears again.

M. Guettard finishes this memoir with some observations upon the Ierre. This river is lost in the same manner as the Rille; and though it is very near Paris, this singularity is unknown to almost every body; was it not for the account of M. l'Abbé le Bœuf, M. Guettard would have been also ignorant of it. And as he thinks the chief object of a naturalist's observation ought to be the public good, he examines the means which might be employed to restrain the water of the Ierre. The same object has made him add a description of the manner how the Rhône is lost, or rather how its course is disturbed; for it is now very certain that it does not lose itself, but that its channel is extremely confined, in the place where it was pretended that it lost itself, by two mountains, between whose feet it runs. M. Guettard makes it appear that it might not be impossible to widen that place, and give a sufficient channel to the river, which would render it navigable, and be of vast utility to all the country."

Pantologia, Art. Rivers. Phil. Trans. Year 1690. *Mem. de l'Acad. des Sciences.*

SECTION II.

Principal Rivers in the different Quarters of the World.

THE general course of the largest rivers we are acquainted with is from a thousand to two thousand miles; and we have them of this length in every quarter of the world; yet in no instance do we find them much exceeding two thousand miles long. We shall commence our rapid tour with those of

ASIA.

The rivers that here attract our attention are the *Indus* and the *Ganges*.

The INDUS is by the natives called *Sinde* or *Sindet,* and in the Sanscrit language *Seendho.* It is also called Nilab, or the Blue River. The source, both of this and of the Ganges, are to this hour unknown: Major Rennell, and various other geographers, have offered opinions upon the subject, but at present they are opinions and nothing more. It is generally supposed to originate in the mountains of Mus Tag, which, as laid down by Strahlenburg, run from west to east, forming a chain to the south of Little Bucharia. Its comparative course may be about a thousand British miles, when it forms a Delta in the province of Sindi, entering by numerous mouths into the Indian sea.

The tributary streams of the Indus chiefly join it in the northern half of its course, where they form the Panjab, or county of Five Rivers. From the west run into Indus the Kamet, with its auxiliary streams, and the Comul; from the east the Bahut or Hydaspes; the Chunab or Acesinas; the Kauvee or Hydraotes; and the Setlege or Hesudrus, being on the east of the Indus. The whole of this part of Hindustan is even at present but little known to the moderns; and it is uncertain whether the Caggan, a considerable and distant river to the east, joins the Indus or falls into the gulph of Cutch.

The GANGES is a still nobler stream, both in magnitude and length; for it is swelled by tributary streams of still greater number and power, and its comparative length can be scarcely estimated at

less than fourteen hundred British miles. The Burramport, or Burrampooter, which is its proudest auxiliary, is nearly as long as itself; it is generally conceived that their sources are not very distant from each other, though we have no decisive information upon this subject, and they separate from each other to the distance of a thousand miles before they unite and constitute one common stream, falling at length into the Bay of Bengal by several mouths. *Ganga*, we have already observed, is an Hindoo term for river generally, and is peculiarly applied to the river before us on account of its unrivalled magnificence The Hindoos bear a superstitious veneration for all the great rivers which fertilize their country; but the waters of the Ganges are held peculiarly sacred. What tends to increase the veneration which is paid to the Ganges is, that its impetuous force, by which it has opened a passage through mount Himmeleh and re-appears, amidst impending rocks, which the natives consider as forming a strong resemblance to the head of a cow, expanded to an immense size, an animal which is as highly esteemed by the Hindoos as the apis or sacred ox was in ancient times among the Egyptians. No river in the world imparts greater benefits to the regions through which it passes; for by annually overflowing its banks like the Nile, it waters and manures the country to an extent of an hundred miles. The Hindoos having deified this river, make it an act of religion to go in pilgrimage to it; they suppose the waters to purify from defilement such as bathe in them, and they bury their dead in its slimy shore. It is, moreover, customary with them to remove those who are on the point of death to the banks of the Ganges, or of some creek which runs into it; for, if an Indian dies in his own house, it is rased to the ground. The Hindoos do not always bury their dead, but as frequently burn the corpse, when the ashes are carefully collected by the bramin, who presides at the ceremony, and thrown into the sea or nearest river. Those who can afford the expence, have such ashes put into an urn, which is soldered up, and carried to be thrown into the water of the Ganges. Rude simplicity is ever prone to mistake the blessings of the Deity for the Deity himself *.

* There is a very excellent paper upon the course of the Ganges and Burrampooter from the pen of Major Rennell, in the Philosophical Transactions, Vol. LXXI. art. ix, but too long for insertion in the present work. The reader who is desirous of pursuing the subject farther, may turn to it with great advantage.
EDITOR.

Besides these majestic rivers we ought not to leave unnoticed the Penjab; the Godaveri, or Ganga; the Nerbudda; the Kistna, a stream peculiarly sacred, that rises at Balisur, not far to the south of Poonah, and is equally celebrated for the fertility it diffuses, and the rich diamond mines which it visits, particularly those of Visiapour and Golconda; the Pennan; the Paliar; and the Caveri, which last passes by Seringapatam, the capital of Mysore, forming a wider delta or triangle than any other northern river, and entering into the sea after a course of about three hundred miles.

The EUPHRATES is derived from two sources; one of which is about seventy miles from the shores of the Euxine or Black Sea, and running a circuitous course of five hundred leagues, first south westward, and then south-eastward, discharges itself into the Persian gulf. About an hundred miles north-west of Bassora it is joined by the TIGRIS, which rising near the Euphrates, proceeds in a pretty straight course through Armenia Major, or Turcomania, until it forms its junction. On this river the ancient city of Nineveh is supposed to have stood.

In the enormous extent of the Chinese empire there are two rivers, that on account of their length and majestic breadth, are peculiarly entitled to notice. These are the Hoanho or Yellow River, and the Kian-ku.

The sources of the first are two lakes, situated amongst the mountains of Tartary, known by the name of Kohonor. They lie about the 35° of north latitude, and 19° of longitude, to the westward of Pekin, being according to Arrowsmith's map of Asia, about 97° east from Greenwich. This prodigious river is extremely winding, and deviates in its course, pursuing a north-east direction to about the 42° of north latitude; when, after running due east, it suddenly bends south to a latitude nearly parallel to its source, and pursues an easterly direction till it is lost in the Yellow Sea. Its comparative course may be estimated at about 1800 British miles, or, according to Lord Macartney's embassy, 2150. At about 70 miles from the sea, where it is crossed by the imperial canal, the breadth is little more than a mile, and the depth only about nine or ten feet; but the velocity equals about seven or eight miles in the hour.

The Kian-ku rises in the vicinity of the sources of the Hoanho; but according to the received accounts and maps, about 200 miles

further to the west, and winds nearly as far to the south as the Hoan-ho does to the north. After washing the walls of Nankin, it enters the sea about 100 miles to the south of the Hoauho. The Kian-ku is known by various names through its long progress; and near its source is called by the Eluts, Porticho, or Petchon: the course is about equal to that of the Hoan-ho; these two rivers being considered as nearly or altogether the largest on the face of the globe. They certainly equal if they do not exceed the famous river of the Amazons in South America, and the majestic course of the Ganges does not extend half the length. In the embassy of Lord Macartney, the length of the Kian-ku was estimated at about 2200 miles; and it is observed that these two great Chinese rivers, taking their source from the same mountains, and passing almost close to each other in a particular spot, afterwards separate from each other to the distance of 15° of latitude, or about 1050 British miles, and finally discharge themselves into the same sea, comprehending a tract of land of about 1000 miles in length, which they greatly contribute to fertilize.

AFRICA.

Of the rivers of Africa, the NILE is the most celebrated; it is also called *Abanchi*, which, in the Abyssinian tongue, signifies "the father of rivers," and by the Africans *Neel Shem*, which means the Egyptian river. It divides Egypt into two parts. The extent of this river is supposed to be something more than two thousand miles from its source, amidst the mountains of the Moon, in Upper Ethiopia, to its disemboguing into the Mediterranean Sea, by seven channels, through which it has forced its way, two only of which are now navigable. The ancients were entirely ignorant of the source of this river, although many endeavours were used to explore it; but its sources are now well known to lie in about the 12th degree of north latitude. It enters the lake of Dambia, in Abyssinia, crossing it one end with so violent a rapidity, that the waters of the Nile may be distinguished throughout their progress, which is six leagues. Here, according to Lobo, commences its magnificence; and its general course we may venture to give in the picturesque but correct description of Thomson.

The treasures these, hid from the bounded search
Of ancient knowledge; whence, with annual pomp,
Rich king of floods! o'erflows the swelling Nile.
From his two springs, in Gojam's sunny realm
Pure-welling out, he through the lucid lake
Of fair Dambea rolls his infant stream.
There, by the Naiads nurs'd, he sports away
His playful youth, amid the fragrant isles,
That with unfading verdure smile around.
Ambitious, thence the manly river breaks;
And gathering many a flood, and copious fed
With all the mellow'd treasures of the sky,
Winds in progressive majesty along:
Through splendid kingdoms now devolves his maze,
Now wanders wild o'er solitary tracts
Of life-deserted sand; till, glad to quit
The joyless desert, down the Nubian rocks
From thund'ring steep to steep, he pours his urn,
And Egypt joys beneath the spreading wave.

Lobo, from whom Thomson has copied his description, informs us in addition, that "Fifteen miles farther, in the land of Alata, it rushes precipitately from the top of a high rock, and forms one of the most beautiful water falls in the world. After this cataract the Nile again collects its scattered stream among the rocks, which seem to be disjointed in this place only to afford it a passage. They are so near each other, that in my time, says he, a bridge of beams, on which the whole Imperial army passed, was laid over them. Sultan Segned has since built here a bridge of one arch, to construct which he procured masons from India."

Egypt is generally divided into Lower, Middle, and Upper. The greatest part of Lower Egypt is contained in a triangular island, formed by the Mediterranean sea and the two great branches of the Nile, which dividing itself five or six miles below Old Cairo, one part of it flows to the north-east, and falls into the sea at Damietta, the ancient Pelusium; while the other branch runs toward the north-west, and falls into the sea at Rosetto: hence this part of Egypt is called "the Delta," from the resemblance which it bears to the shape of the Greek letter of this name, constituting a triangle.

The water is thick and muddy, especially when the river is swelled by the heavy rains which constantly fall within the tropics in the beginning of our summer, and which are doubtless the principal cause of its annually overflowing the low lands of Egypt. The ancients, who were not much acquainted with the climates in these latitudes, were for the most part considerably perplexed when they endeavoured to account for this annual deluge. Lucretius, however, has assigned its cause with his usual accuracy and ingenuity in the following lines: Rer. Nat. vi. 1712.

Nilus in æstatem crescit, campisque redundat,
Unicus in terris, Ægypti totius amnis:
Is rigat Ægyptum medium per sæpe calorem
Aut, quia sunt æstate aquilones ostia contra
Anni tempore eo, qui Etesiæ esse feruntur;
Et, contra fluvium flantes, remorantur; et, undas
Cogentes sursus, replent, coguntque manere.
Nam, dubio procul, hæc adverso flabra feruntur
Flumine, quæ gelidis ab stellis axis aguntur:
Ille ex æstiferâ parte venit amnis, ab austro
Inter nigra virûm percocto secla colore,
Exoriens penitus mediâ ab regione diei."—&c.

The Nile now calls us, pride of EGYPT's plains:
Sole stream on earth its boundaries that o'erflows
Punctual, and scatters plenty. When the year
Now glows with perfect summer, leaps its tide
Proud o'er the champaign; for the north wind, now,
Th' ETESIAN breeze, against its mouth direct
Blows with perpetual winnow; every surge
Hence loiters slow, the total current swells,
And wave o'er wave its loftiest bank surmounts.
For that the fixt Monsoon that now prevails
Flows from the cold stars of the northern pole,
None e'er can doubt; while rolls the Nile adverse
Full from the south, from realms of torrid heat,
Haunts of the ETHIOP-tribes; yet far beyond
First bubbling, distant, o'er the burning line.

Then ocean, haply, by th' undevious breeze
Blown up the channel, heaves with every wave
Heaps of high sand, and dams its wonted course;
Whence narrower, too, its exit to the main,
And with less force the tardy stream descends.
Or, towards its fountain, ampler rains, perchance,
Fall, as th' ETESIAN fans, now wide-unfurl'd,
Ply the big clouds perpetual from the north
Full o'er the red equator; where condens'd
Pond'rous and low, against the hills they strike,
And shed their treasures o'er the rising flood.
Or, from the ETHIOP-mountains, the bright sun
Now full-matur'd, with deep-dissolving ray
May melt th' agglomerate snows, and down the plains
Drive them, augmenting hence, th' incipient stream.

GOOD.

These ingenious conjectures of the cause of the periodical exundations of the Nile, have been in a considerable degree verified by modern observations: but the poet is mistaken in conceiving that the Nile is the only river that periodically overflows its banks: we have already noticed a similar phænomenon in the Ganges; and it is the same with all the rivers which have either their rise or course within the tropics; they annually break their bounds, and cover the lands for many miles before they reach the sea. They likewise leave a prolific mud, which, like that of the Nile, fertilizes the land; and, though the waters of these rivers are also very thick yet when they have stood for some time, they are neither unpalatable nor unwholesome. The north winds, moreover, which begin to blow about the latter end of May, drive in the waters from the sea, and keep back that of the river, in such a manner as to considerably assist the swell.

The Egyptians, and especially the Cophts, are persuaded that the Nile always begins to rise on the same day of the year; and, indeed, it generally commences on the 18th or 19th of June. From accounts of its rise for three years, Dr. Pococke observes, that he found it ascend the first five days from five to ten inches; and it thus continued rising till it had attained the height of six

cubits, when the canal of Cairo was cut: after this it continued rising six weeks longer; but then it only rose from three to five inches a day; for, spreading over the land, and entering the canals, though more water may descend than before, yet its rise is less considerable; as after the opening of that canal, the others are unclosed at fixed times, and those that water the lower grounds the last. These canals are carried along the highest parts of the country, that the water may hence be conveyed to the vallies.

The Nile has one character of great peculiarity. Other rivers being supplied by rivulets, the ground is lowest near the banks: but as no water flows into the Nile in its passage through Egypt, and as it is necessary that this river should overflow the land, the country is generally lower at a distance from the Nile than near it; and in most parts of the land seems to have a gradual descent from the Nile to the foot of the hills, which may be said to begin at those sandy parts already mentioned, as being a mile or two distant from them, which, rising toward the mountains ina gentle ascent, are never overflowed.

The cataracts of the Nile will be described in a subsequent section.

The SENEGAL is the next most remarkable river in Africa; called by Ptolemy *The Daradus*. D'Anville, who follows that ancient geographer, supposes it to take its rise among the mountains af Caphas, lying about 14° north latitude, and nearly on the meridian of Greenwich. It takes a western course, tending somewhat to the northward, through sixteen degrees of longitude, and, including its bendings, must extend more than eleven hundred miles. It has this very distinguishing peculiarity, that when arrived within fifteen miles of the sea, it winds suddenly round to the south, and proceeds in that direction through more than seventy miles, when it discharges its waters into the sea, forming at its mouth the little island of St. Louis, in latitude 16° 10′ north. This river is said to be navigable for near three hundred leagues up the country; but the dangers to which Europeans are exposed by the ferocity of the natives who inhabit its banks, deter from all endeavours to explore it, such attempts having proved fatal to most of those who have ever embarked in it.

Some geographers have supposed the Senegal to be a continuation

of the NIGER; but such an opinion is now generally held to be erroneous; it being believed that the Niger discharges its rapid stream into a lake not more than sixty miles distant from another lake of great depth called *Maberia*, whence issues one of the sources of the Senegal; but these two lakes are intersected by a ridge of lofty mountains. The Niger is said by d'Anville, likewise, to bear the names of the *Guin*, or *Ica*. That geographer chiefly follows Ptolemy in his description of this river. He lays it down in his map as springing from two lakes about two hundred and fifty miles distant from each other; the one he calls *Semegoud*, the other *Regebib*; he places the most southern in 13° north latitude, while the other, which is the most eastern, lies about the twentieth degree of east longitude from Greenwich. The winding course of this wide and land-girt river, tends to the westward; and is supposed to terminate in another lake, called by Ptolemy *Marais*, and which d'Anville lays down in 15° north latitude, and 3° west longitude from Greenwich.

The GAMBIA is likewise a river of very extensive course, wide, and rapid, to the south of the Senegal, and in its progress from its source to its disemboguing, proceeds in a direction very similar to the latter. It discharges itself into the Atlantic in 13° north latitude.

In addition to what has been remarked by Ptolemy, d' nville, and other writers, may be subjoined the following more recent information contained in the evidence given by Mr. Barnes to the lords of the committee of council, as laid before the house of commons in the year 1792.

"The river Senegal," says he, "is supposed to take its rise from the western declivity of the mountains of Govina. The river Niger takes its rise from the eastern declivity of these mountains," according to d'Anville. The Africans navigate both these rivers, and in places where there are cataracts, carry their goods upon asses. The French trade in small vessels to fort St. Joseph, which is near three hundred and sixty leagues up the river Senegal, and go sometimes as far as the first cataract, which is about twenty leagues farther, where they purchase slaves, who are supposed to be brought from places two hundred or three hundred leagues higher up the country." St, Joseph lies in about 10° 15′ west longitude from Greenwich.

This great river is extremely rapid at its mouth, which is attributed to so large a body of water being confined within so narrow a channel, the mouth of the river being only half a league over, and choaked up by a bar, which renders the passage exceedingly difficult and dangerous, especially in the rainy season, when the prodigious swell of the river, and the south-west winds, opposed to its rapid course, raise waves of so prodigious a height at the bar, that their clashing resembles the shock of mountains, and are said to be so furious as to dash in pieces the stoutest ships: yet, according to Labat, the worst season, with respect to commerce, is in September and November, when the winds blowing northerly, exclude all navigation, even of the smallest boats.

This bar is doubly dangerous, not only on account of the violence of the waves, but of the shallowness of the water, and the shifting of the bar after floods and heavy rains, by which the channels are lost, and new soundings become necessary to discover them. The Senegal would indeed be quite shut up were it not for one channel, four hundred yards broad, and two fathoms deep, that has long kept its present direction. The most proper time for crossing the bar is from March to September, when the winds are variable, and the bar continues fixed till the ensuing rainy season.

When the bar is crossed, a smooth and gently-gliding river is entered, which is four fathoms deep.

These rivers have likewise their inundations, which overspread the whole flat country of Nigritia. They begin and cease much about the same time as the Nile overflows, but no such salutary effects are experienced here as in Egypt; for, instead of health and plenty, diseases, famine, and death, follow in their train. The soil thrown up by the Senegal, becomes unavailing to any agricultural purposes, from the indolence of the savage wanderers who occupy its banks, and the country lying untilled, from its luxuriance produces great abundance of rank and noxious herbage, and furnishes a convenient repository for venomous insects and reptiles, as well as for beasts of prey. When the waters of these rivers retire into their channels the humidity and heat which prevail spread a pestilential taint, whilst the carcases of vast numbers of animals, which the inundation had swept away, become putrid, and spread around a loathsome and baneful stench. Even the vegetation itself is charged with destruc-

tion; for among the plants which grow on the banks of the Senegal, some diffuse a scent so powerful as to be insupportable to the nerves of smell.

Turning from these scenes of desolation and horror, let us survey the grand and beneficial assemblage of rivers which are dispersed over the countries of

EUROPE.

The WOLGA, or VOLGA, is the river most extensive in its course of any which rises in Europe, being above two thousand miles in length; the whole of which it passes through the Russian territories, when it enters Asia about 48° 30′ north latitude, discharging its waters into the Caspian sea, by various channels, below Astracan, and at the same time producing many islands.

D'Anville, who lays down the sources of this great river with his wonted precision, makes the chief of them to issue from lake Ilmen, in the government of Novogorod, about 58° north latitude; while the next most considerable he derives from a much smaller lake, to the south-east, in the government of Twer. These two streams, the latter of which, by more modern geographers, has been called the river *Twerzo*, unite at the town of Twer, near which the Wolga first becomes navigable. On this subject Mr. Coxe speaks as follows; The vast forest of Volkonski, which extends on the side of Smolensko one hundred and fifty miles, almost to the gates of Moscow, gives rise to the principal rivers of European Russia, such as the *Duna*, the *Nieper*, and the *Volga*; the sources of the two latter rise at small distances from each other, not far from Viasma.

The banks of the Volga are generally fertile; and though not sufficiently cultivated, on account of the frequent incursions of the Tartars, yet the soil naturally produces all kinds of esculent plants, and in particular asparagus of a very extraordinary size and goodness. It is observable that most of the oaks in Russia grow in the countries watered by this river. The Volga is navigable for large ships; and toward the end of the spring is so swelled by the melting of the ice and snow as to cause great inundations, particularly in the months of May and June. The masters of the vessels which sail down the Volga to Astracan, carefully observe this season, as they

have now not only the opportunity of a safe passage over the shallows, but also over several flat islands, which lie at a considerable depth under water. The Volga receives several tributary streams, especially the Occa and Cama, and abounds with that species of whale called *beluga*, from ten to eighteen feet in length.

The DON, the Tanais of the ancients, is called Tuna or Duna by the Tartars, and has its source not far from Tula in the Iwano Ossero, or St. John's Lake. It first runs from north to south, and after its conflux with the Sosna, directs its course from west to east, and in several large windings again runs from north to south, but at length, dividing into three channels, falls into the sea of Asoph. The waters of the Don are thick and chalky, consequently not a very pleasant drink. This river is very shallow in summer, when it is also full of sand-banks; it, however, affords plenty of large and small fishes. In its course it approaches so near the Volga, that in one place (latitude 49°), the distance between them is but one hundred and forty wersts, or about eighty English miles, which led Peter the Great to form a design of joining these two rivers by means of a canal, and some progress was made in the work, but he did not live to complete it, and his successors have not thought fit to resume the project.

The DWINA is a very large river: the name signifies *double*, it being formed by the conflux of the Sukona and the Yug. This river divides itself into two branches or channels near Archangel, whence it runs into the White Sea.

The NIEPER, the ancient Borysthenes, rises from a morass in the forest of Volconski, about one hundred and twenty miles from Smolensko, and makes several windings through Lithuania, Little Russia, the country of the Zaporo Cossacks, and a tract inhabited by the Nagaian Tartars; and after forming a marshy lake of sixty wersts in length, and in many places two, four, or even ten in breadth, discharges itself into the Black Sea. The banks of this river are on both sides generally high, and the soil excellent; but in summer the water is not very wholesome. The Nieper has no less than thirteen water-falls within the space of sixty wersts; yet in spring, during the land-floods, empty vessels may be hauled over them. It abounds in sturgeon, sterled, carp, pike, karaush, &c. There is but one bridge over this river, and that is a floating one at Kiow, one thou-

sand six hundred and thirty-eight paces in length. This bridge is taken away about the end of September, to give the flakes of ice a free passage down the river, and is again put together in the spring. There are to be seen on this river a great number of mills erected in boats.

In describing the rivers belonging to the vast empire of Russia, the NEVA must not be omitted. It issues out of the lake of Ladoga, and in its short course is broad, rapid, and navigable; upon islands formed by the different branches of this river, a considerable part of the city of St. Petersburgh, built by Peter the Great, is erected. Its whole course is no more than forty English miles, and it discharges itself into the gulf of Finland. The Neva is about eight hundred paces broad near St. Petersburgh: but has not every where an equal depth of water, so that large merchant ships are cleared at Cronstadt, and the men of war built at St. Petersburgh are also conveyed thither by means of certain machines called camels. Beside the Neva, the rivers Fontanca and Moica contribute to form the islands on which the new metropolis stands, which is also watered by several canals; for in this respect the emperor took his model from Amsterdam. There is but one bridge over the Neva, which is constructed with large flat-bottomed boats, and joins the dock-yard to Basili Ostrow, or Basil's Island. These are laid across the river in the spring, so as to form a safe and convenient passage; but they are always removed in the autumn, before the frost begins. The only communication between the other islands is either by boats or barks, which cross the water at stated times; but bridges are built over the Moica and Fontanca, and likewise over the canals. St. Petersburgh is much exposed to inundations: in September 1777, one rose to a very great height, and did prodigious injury, especially to the property of the merchants.

The DANUBE, the ancient Ister, is the next considerable river in Europe, in which quarter it rises and terminates. Its whole course is near fourteen hundred miles. Its source is in Swabia, within a few miles of the borders of Swisserland, latitude 48° N. longitude 9° E. whence the Rhine issues; the direction of the Danube is eastward, that of the Rhine north-westward. The former intersects Bavaria, Austria, Hungary, and at Vaez, a town in the latter kingdom, turns southward. It ...des the bannat of Temesvar from

Servia, and Wallachia from Bulgaria, discharging itself into the Euxine or Black Sea, by several channels, about 45° north latitude and 29° east longitude, with such violence, that its waters are distinguishable for several miles from those of the sea into which they are precipitated. It is said to receive sixty navigable rivers in its course, and an equal number of smaller streams. From Buda, in the centre of Hungary, to Belgrade, on the northern confine of Servia, it is so deep, as well as broad, that in the wars between the Christians and the Turks, each power has had fleets upon it, and frequent naval engagements have taken place; farther down it is rendered unnavigable by its many cataracts, so that all commerce with the Black Sea by means of this great river is rendered impracticable.

Of all the parts of Europe, Swisserland is the country in which the greatest number of rivers take their rise. The principal are the RHINE, a name given by the Swiss to streams and rivers in general: its sources are in the country of the Grisons, and are divided into the Anterior, the Middle, and *Hinter*, or Hinder. The Anterior or Upper Rhine issues from a small lake on a mountain commonly called the Oberalp, and by some Cima de Baduz. The source of the Middle Rhine lies in Luckmanier, a part of the Adula chain, and, after a course of about eighteen miles, joins the Anterior Rhine. The Hinder Rhine rises about nine miles distance, in a mountain called by the Italians Monte del Uccelo, or Bird's-hill. The Rhine is first formed by a water which issues out of two rocks of ice on the Furka chain, and precipitates itself with a thundering noise between two rocks of an astonishing height, which receiving several rivulets in its course, runs into the lake of Geneva, and re-issuing from it, traverses the vicinity of that city, and after watering a small part of Savoy, enters France. The Russ or Reufs is an adjoining river which issues from the Lake Luzendra, on the mount St. Gotthard, and having joined two rivulets, precipitates itself through a deep and narrow valley down several rocks; but at length becomes more gentle, and then falls into the lake at the Four Forest Towns; but at Lucerne again makes its appearance under its former name, and soon after receives the Lesser Emmat, or Emmen, which rises in the mountains, and at last discharges itself into the Aar, Aren. This last river, which proceeds from the mountain of Grimsel, at length falls

into the Rhine. The Tesin, in Italian Tesino, rises partly from two lakes on the mount St. Gotthard, and partly from several other lakes on the mountains, and after passing through the valley of Levis, and the Lago Maggiore, enters the dutchy of Milan, and at length loses itself in the Po. The Rhone, another river which rises in Swisserland, will be spoken of hereafter.

Not far from the rise of the Rhine, at a small distance from the lake Constance, a very singular bridge is thrown over that river at Schaffhausen, which is much admired for the beauty and singularity of its architecture, and was built about the middle of last century. The rapidity of the river had carried away several stone bridges, built upon arches of the strongest construction; at length a common carpenter, named Ulric Grubenham, undertook to throw a wooden one, of a single arch, across the river, although it is more than three hundred feet wide. The magistrates, however, insisted that it should consist of two arches, and that he should make use, for that purpose, of the middle pier of the old bridge, which remained entire. The architect obeyed, but he constructed his bridge in such a manner that it is not at all supported by the middle pier; and it would have been equally safe, and considerably more beautiful, had it consisted solely of one arch. The sides and top of this bridge are covered, and the road over it is nearly level. It is what the Germans call a hängewerk, or hanging bridge; the road not being carried over the top of the arch, but along the middle of it, and there suspended. The middle pier is not quite in a right line with the side piers, which rest on each shore, but forms with them a very obtuse angle, pointing down the stream. The distance of the middle pier from the shore next the town is one hundred and seventy one feet, and from the other side one hundred and sixty-four, making in appearance two arches of a surprising width, and forming a most beautiful perspective when viewed at some distance. A man of the slightest weight, when walking upon it, feels it tremble under him, yet waggons heavily laden pass over it without danger, and although in the latter case the bridge seems almost to crack with the pressure, it does not appear to have suffered the least damage. What seems almost incredible is, that the architect was totally ignorant of mathematics, and knew nothing of the theory of mechanics, so that this wonderful undertaking was accomplished merely by the force of natural abilities.

Engraved by ... from a Drawing by ...

For the Gallery of Nature & Art

FALL OF THE RHINE NEAR THE BRIDGE AT SCHAFFHAUSEN.

The Rhine runs westward to Basil, and then proceeds in a direction due north, along the eastern border of Alsace, till it receives the Maine, a little below Frankfort, then proceeding north-westward, it enters the Netherlands. Its whole course cannot be less than seven hundred miles; the cities of Mentz, Coblentz, Cologne, Dusseldorf, Wesel, and Cleves, are situated on its banks. The circles of the Upper and Lower Rhine are intersected by it. In its course along Alsace, it frequently causes terrible devastations, not only in winter, but in the midst of summer, when the snow melts on the Alps. Its inundations then ruin the fields, by covering them with sand. The violent torrents of the Rhine, which generally happen every year, frequently alter the situation of the islands within it. One singularity of this river is, that in its sand are found particles of gold, which the torrents in their fall wash from the Alps, and bring into it; hence it is only below Basil that the sand contains this precious mixture, which in autumn and winter, when the river is at the lowest, is drawn out with the sand, from which, after passing through several waters, the gold is extracted. The particles of this metal are seldom so large as a grain of millet; the gold is indeed very fine and beautiful; but is so scarce, that the city of Strasburg, which has the privilege of gathering gold for the length of four thousand paces, scarce collects five ounces in a year. The Rhine also contains many crystals, and particularly pebbles, that receive a beautiful polish, and are much used in France under the name of Rhine pebbles.

At Utrecht it divides itself into two branches, which are called the Old and New Rhine, both of which traverse the city through its whole length; one of these branches loses itself in the sands below Leyden, the other takes the name of the Lech, and falls into the Mayne. Thus does this grand and important river, after so long and useful a course, terminate obscurely, without pouring its aggregated waters into the common receptacle, the ocean!

The RHONE or RHODIAN, rises in the Glacier of Furca, near the province of Uri, in Swisserland, but in the north-eastern border of the Valais. At first it precipitates itself with great noise among several rocks, and down to the very plain in the valley has the appearance of a single cataract, with several cascades. It is afterwards joined by the Meyenwang stream, which issues from the

Grimsel mountain, and then directs its course from east to west, till, after a winding northward, it discharges itself with great impetuosity into the lake of Geneva: all the streams and lesser rivers of the Valais issuing from the mountains mingle with it.

The waters of the Rhone rush into the lake with such rapidity, that for the distance of half a league, they continue unmixed with those of the lake, the one being very foul, and the other very clear; but afterwards, says Keysler, there is no visible distinction, though some of the ancient, and some modern writers, affirm the contrary. At its efflux from the lake it forms an island, on which, together with the banks on both sides, the city of Geneva is built, being divided into three unequal parts, which have a communication by four bridges. Onward it forms the boundary between France and Savoy. It then takes a westward direction, and dividing the late province of Burgundy from that of Dauphiny, it flows to Lyons, from which city it proceeds due southward, forming the eastern boundary of Languedoc, and at the city of Avignon begins to divide it from Provence. It discharges its waters into the Mediterranean by several mouths, a little below Arles. On the banks of the Rhone, between Valence and St. Valiere, a peculiar kind of grape is cultivated, from which an agreeable, but roughish, red wine is procured, which bears the name of *hermitage*, and is considered as very wholesome, as well as excellent in point of taste.

The VISTULA, or WEISEL, in Polish the Wisla, rises among the Carpathian mountains, on the confines of Silesia and Upper Hungary; its course is in a north-west direction through Little Poland, a part of Masóvia, of Great Poland, and of Prussia, and falls by three mouths into the Baltic, below Dantzic. Warsaw, the capital city of Poland, and Thorn, once a place of considerable trade, are situated on its banks. Great quantities of grain and timber, the growth of Poland, are sent down this river to Dantzic, and there exported to foreign countries; but this trade has been greatly checked of late by the heavy duties imposed upon it.

The ELBE rises in the Giants' Mountain, in the principality of Jauer, in Silesia, not far from the source of the Vistula. In Saxony it divides the capital city Dresden into what is called the Old and New Town, which are united by a stone bridge, six hundred and eighty-five paces long, and seventeen broad, containing eighteen

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SUBTERRANEAN DISAPPEARANCE OF THE RHONE, NEAR GENEVA.

arches. Meissen, ten miles north-west of Dresden, is likewise situated on this river, over which is a bridge, supported by stone piers, but the upper part is of wood: this bridge is considered as a masterpiece of art, the middle arch, which is seventy-five paces wide, being kept together by a single wooden peg. The Elbe bounds the Old Mark of Brandenburg toward the east, and there receives the Havel. It is the principal river in Lower Saxony. At Hamburg it becomes extremely broad, and has sufficient depth for large ships: it discharges its waters into the German Ocean, by the fortress of Glukstadt. Few kinds of fishes are found in this river.

The principal rivers of FRANCE which have their sources in that kingdom are the Loire, the Garonne, and the Seine; these all discharge their waters into the Atlantic. The LOIRE is a larger river than the Rhone. It rises in the mountains of Cevennes, in Languedoc (now distributed into five departments); it takes its course north and north-west, till it passes the city of Orleans, in the Orleanois (now the department of the Loire); it afterward pursues a course south-west and west, by Tours and Angers, and discharges itself into the Bay of Biscay, forty miles below Nantes; its whole course, with all its windings, is computed to be five hundred miles, receiving in its progress the Allier, Cher, Indre, Creuse, Vienne, and Maine. It has a communication with the Seine by means of the canals of Briate and Orleans. In November 1790, it overflowed its banks, and laid a large extent of country under water.

The GARONNE rises at the foot of the Pyrenees, in the county of Cominges; it becomes navigable at Muret, on the confines of Languedoc; in its course it is joined by many rivers; it passes Toulouse and Bourdeaux, below which it receives the Dordogne, a river nearly equal to it in consequence; these united streams then take the name of the Gironde, become very broad, and disembogue into the bay of Biscay. By means of this river, and a noble canal, a junction has been formed between the Mediterranean Sea and the Atlantic Ocean. This canal is a work of such grandeur and utility that we cannot consent to pass it by without a more detailed description.

The ROYAL CANAL, formed in order to make a communication between the Atlantic Ocean and the gulf of Lyons, in the Mediterranean, of such extent, that vessels might pass from one sea into the other without going round by Spain, is in truth one of the noblest

works that any country has ever produced. Under Louis XIV, Paul Riquet, of Bezieres, after employing twenty years in a minute consideration of every particular relating to it, during which he had no other counsellor than his gardener, completed his plan. The first stone was laid in the year 1667, and the canal was opened in 1681, but it was not completed until many years after.

It begins in the harbour of Cette, on the Mediterranean, and traverses the lake of Thau, and a quarter of a mile below Toulouse is conveyed by three sluices into the Garonne. It is every where six feet deep; so that a cargo of eighteen hundred quintals may be forwarded to any place upon it, and its breadth, from one bank to the other, is a hundred and forty-four feet.

At St. Ferreol, a quarter of a mile below Revel, between two rocky hills, that are in the form of a half-moon, is a large reservoir, twelve hundred fathoms in length, five hundred in breadth, and twenty deep, the whole surface being six hundred and eighty-seven thousand four hundred and thirty-eight feet. Into this bason of water the rivulet of Laudot, which runs down the hills, is received, and inclosed by a wall two thousand four hundred feet long, a hundred and thirty-two in height, and twenty-four feet thick, having a strong dam, defended by a strong wall of free stone. Under the dam runs an arched passage reaching to the main wall, where three large cocks, of cast brass, are turned and shut by means of iron bars; and these cocks discharge the water, through mouths as large as a man's body, into an arched aqueduct, where it runs through the outer wall, beyond which it goes under the name of the river Laudot; continuing its course to the canal called Rigole de la Plaine. Thence it is conveyed to another fine reservoir, near Naurouse, two hundred fathoms in length, a hundred and fifty in breadth, with the depth of seven feet; and out of this bason is conveyed, by means of sluices, both to the Mediterranean Sea and to the ocean, according as the canal requires it. Though the above cocks remain open for some months successively, yet there is no visible diminution of the water in the great reservoir. Near Bezieres are eight sluices, which form a regular and grand cascade, nine hundred and thirty-six feet long, and sixty-six high, by means of which vessels may pass across the river Orb, and continue their voyage on the canal. Above it, between Bezieres and Gapestan, is the Mal-Pas, where the canal is conveyed for the length of a hundred and twenty fathoms,

under a mountain cut into a very lofty arcade, the greatest part of which is lined with free-stone, except toward the end, where it is only hewn through the rock, which is of a soft calcareous substance. At Agde is a round sluice, with three openings, three different depths of the water meeting at this place; and the gates are so ingeniously contrived, that vessels may pass through by opening which ever sluice the master pleases; an invention that struck the great Vauban himself with admiration. The lesser rivers and streams, that might have prejudiced the canal, have been carried under it by water-courses, forty-four in number, beside eight bridges.

This canal cost thirteen millions of livres (something more than half a million sterling), part of which money was furnished by the king, and part by the states of Languedoc. The king generously granted to Riquet, the projector and conductor, and his male heirs, all the jurisdiction and revenues belonging to it; so that the crown was not to come into possession till the extinction of his family. Ships passing on it, for every hundred weight paid twenty sous (10*d.* English), and even the king himself paid the same toll for military stores, &c. sent by way of this canal; so that the revenue, especially in time of a brisk trade, was very considerable. However, the charges attending it are also very great; for the salaries of the several directors, receivers, comptrollers, lieutenants, clerks, and watchmen, annually amount to one hundred thousand livres (4000*l.* sterling), beside an enormous great expence in repairs. The Counts of Caraman, descendants of Riquet, were also obliged to keep passage-boats, which are drawn by mules or horses; these go and return at stated times. According to Mr. Swinburne, 360 boats navigate this canal, each of which perform annually six voyages. The conveyance of goods is paid for by the league, passengers pay by the day. The proprietors of the works receive a thousand livres (43*l.* 15*s.* sterling) each voyage. The whole annual income, the same writer states to be 2,160,000 livres (94,500*l.* sterling), the current expences and costs of repairs are supposed to amount, one year with another, to 1,610,000 livres (70,437*l.* 10*s.* sterling) per annum, and the net profits to 550,000 livres (24,062*l.* 10*s* sterling). The length of this canal from Toulouse to Bezieres, where it joins the river Orb, is 125,435 French toises, equal to one hundred and fifty-two English miles. "The system of inland navigation," observes the same writer, "has been so much improved of late

years, that I make no doubt that this canal would be shortened many leagues, were it to be undertaken afresh. It is full of angles and turns that do not appear necessary; and on the contrary, in one or two places has been driven straight at an enormous expence, through numberless obstacles, when a short sweep would have conveyed the waters, with greater ease, and less expence, to the place of their destination. There are fifteen locks upon it in the fall toward the ocean, and forty-five on the side of the Mediterranean. The highest point between the two seas is at Naurouge, which is elevated one hundred toises (more than two hundred yards) above the level of each shore. The canal is carried over thirty-seven aqueducts, and crossed by eight bridges."

The SEINE rises near Dijon, in Burgundy (now the department of Cote d'Ore); it proceeds in a north-western course. On this river Paris is situated. It consists of three parts, independently of its twelve suburbs, namely, the town, which lies on the north of the Seine, the city, which is environed by that river, and the university, which lies to the south of it. The city comprises three islands, formed by the Seine, which are, l'Isle du Palais, l'Isle de St. Louis, and l'Isle Louviers: the last is small, and contains only storehouses for wood. The isle du Palais communicates with other parts of the city by means of seven stone bridges, the principal of which is the Pont Neuf, or New Bridge, the finest bridge in Paris. It consists of twelve arches, and is seventy-two feet broad, reckoning the parapets. The middle, or carriage-way, is thirty feet broad, and on each side is a raised footway.

Over the piles on either side are also semicircular lodgments, in which are an hundred and seventy-eight small shops, formerly belonging to the king's footmen, which, like those formerly disfiguring London-bridge, only serve to obstruct a most beautiful prospect. In the centre of the bridge stood once a fine equestrian statue of Henry IV. in brass, larger than life, and standing on a marble pedestal, on the sides of which were basso relievos, with inscriptions, representing the victories and principal actions of that hero. At the four corners were tied four slaves, also of brass, who trample upon antique arms. This stately monument was inclosed within iron rails. Another ornament of the Pont Neuf is the Samaritaine, a building three stories high, in which is an engine that supplies some parts of the city with water. It was thus named from its containing in the front a groupe

of figures representing the story of Christ and the Samaritan woman. These statues were taken down by order of the National Convention.

Another bridge, called the PONT AU CHANGE, had also a statue of Louis XIV. in brass; and both this and the bridge of Notre Dame, on which are also water-works, have each two rows of houses upon them; those of the first being four, and of the last two stories high.

The Seine, passing through Normandy (now divided into five departments), visits Rouen, and falls into the British Channel near Havre de Grace.

The great and small rivers in SPAIN are said to amount to an hundred and fifty; the principal of these are the Minho, which rises in Galicia; the Douro, which has its source in Old Castile, in a part of the mountains of Idubeda; the Tagus, rising in a mountain in New Castile, which it passes through, the city of Toledo being situated on its banks, and the river encompassing it in the form of a horse-shoe. It bounds the Portuguese province of Beira to the south, passes through that of Estramadura, and discharges itself into the Atlantic. Lisbon, the capital of Portugal, is situated near its mouth. All the great rivers of PORTUGAL have their sources in Spain. Thus the Guadiana also issues from New Castile, deriving its source from some lakes, at a small distance from which it takes its course between high mountains, in which it conceals itself for near three miles, and then re-appears in a fenny soil, but soon hides itself again amidst reeds and rocks, which probably gave occasion to the mistaken idea of its losing itself under-ground. This river separates the Spanish province of Andalusia from Portuguese Algarva. The Guadalquiver, or Great River, by the ancients called Bætis, and Tartessus, begins its course in Andalusia, where several small streams issuing from Mount Segura unite in a lake, from which this river flows. From Corduba to Seville, it is passable only by small craft; but from the last city to its mouth, it is navigable by ships of burden, though dangerous on account of its many sandbanks. The Ebro rises in the mountains of Santillane, in Old Castile, from two springs, and receives upward of thirty brooks in its course, becoming navigable near Tudela; its navigation, however, is dangerous, on account of its many rocks; at length it discharges itself with great rapidity into the Mediterranean, and its mouth forms the little island of Alfacs.

All these rivers abound in fishes; and the three principal, the Douro, the Tagus, and the Guadiana, divide the kingdom of Spain into three parts.

In the province of Andalusia is the river Tinto, or Azeche, the water of which cannot be drunk; it is accused, indeed, of being noxious even to herbs and the roots of trees, and has no kind of fish, or any living creature, to inhabit its waters.

To close the survey of rivers on the European continent, some of those in Italy must necessarily be spoken of; in which country the Apennine mountains take their rise near the Alps, on the sea-coast, in the territories of Genoa, and dividing Italy into almost two equal parts, reach to the straits that separate it from Sicily, and give rise to an incredible variety of rivers that water this delightful country. The largest and most remarkable of the rivers of ITALY are the following.

The Po, which rises in mount Viso, in Piedmont, one of the highest of all the Alps, and after receiving upward of thirty small rivers, discharges itself into the Adriatic, by seven different mouths. It passes through Montferrat, the Milanese and Mantua, laves the borders of the Parmesan, and a part of the Modenese. It often overflows its banks, causing great devastation. The Adige, in Latin *Athesis*, has its source in the Rhætian Alps, and waters the cities of Trent and Verona, it being the only large river in Lombardy, and instead of joining the Po, runs, like that river into the Adriatic. The Arno flowing from the Appennine mountains, and falling into the Tuscan sea near Pisa. The Tiber, which rises out of the Apennine mountains, and at a small distance from Rome, empties itself into that part of the Mediterranean called the Tuscan sea. It is known in Italy by the name of Tivere. Its waters are generally so thick and muddy at Rome, that even horses are not watered in its stream; but after standing two or three days, it works itself clear, and becomes fit for drinking. The bed of the river being raised by the ruins of many houses which have fallen into it, and its mouth much choaked up, it frequently overflows its banks, more especially when a strong south wind blows.

The principal rivers of England are the Thames, the Severn, the Trent, and the Humber.

The THAMES, if considered with respect to its course and navi-

gation, is not to be equalled by any river in the known world. It rises from a small spring a little to the south-west of Cirencester, in Gloucestershire; and, taking its course eastward, becomes navigable at Lechlade for vessels of fifty tons, and there receives the river Colne, about one hundred and thirty-eight miles from London. From Lechlade it continues its course north-east to Oxford, where it receives the Charwell; after which it runs south-west to Abingdon, and thence to Dorchester, where it receives the Thame, and continuing its course south-east, flows by the borders of Berkshire, Buckinghamshire, Surrey, Middlesex, Essex, and Kent. In this extensive progress it passes along a multitude of towns and fine picturesque villages; and having visited London and Westminster, proceeds by Deptford, Greenwich, Woolwich, and Gravesend, to the sea. It is impossible to represent the beauties with which the banks of this noble river are embellished from Windsor to London; besides numerous villages, they are adorned with magnificent seats and gardens of numerous nobility and gentlemen. The tide flows as high as Richmond in Surry, which, following the winding course of the river, is seventy miles from the sea. At London the depth is sufficient for the navigation of large ships, which renders it the greatest port for trade in the universe. The water is justly esteemed exceedingly wholesome, and fit for use in very long voyages, during which it will work itself perfectly fine. It likewise abounds with a great variety of fishes.

The best description of this renowned river is to be found in Sir John Denham's poem of Cowper's Hill. It is as follows; and the fine simile with which it concludes, and particularly the sweetness of the lines in which the simile is conveyed, have been objects of admiration and perhaps of envy by every succeeding poet.

Thames, the most lov'd of all the Ocean's sons
By his old sire, to his embraces runs;
Hasting to pay his tribute to the sea,
Like mortal life to meet eternity.
Nor are his blessings to his banks confin'd,
But free and common as the sea or wind;
Where he, to boast or to disperse his stores,
Full of the tribute of his grateful shores,
Visits the world, and in his flying tow'rs
Brings home to us, and makes both Indies ours;

So that to us no thing, no place is strange,
While his fair bosom is the world's exchange.
O could I flow like thee, and make thy stream
My great example, as it is my theme!
Though deep, yet clear; though gentle, yet not dull;
Strong without rage, without o'erflowing full.

Although it is the current opinion that the Thames had its name from the conjunction of the Thame and Isis, yet it is always called Thames before it comes near the Thame. This the annotator on Camden proves from ancient records, and adds, "it may be safely affirmed, that it does not occur under the name of Isis in any charter or authentic history; and that the name is no where heard of, except among scholars; the common people all along, from the spring-head to Oxford, calling it by no other name but that of the Thames."

The SEVERN rises from a small lake on the vast mountain of Plynlimmon, in Montgomeryshire, and is the principal beauty of the county, in which it receives so many small streams, that it becomes navigable near the town of Montgomery. It passes through the middle of Shropshire; on its banks are the towns of Shrewsbury and Bridgenorth; its course is through the centre of Worcestershire, from north to south, the city of Worcester and town of Tewkesbury being here seated on its margin. Entering Gloucestershire, it runs by the city of Gloucester, and discharges itself into a large bay, which, from the commercial city in its vicinity, is called the Bristol Channel. About fifteen miles from its mouth a navigable canal has been constructed, which conveys the waters of the Severn to within about two miles of Cirencester; they are then carried by a tunnel or archway, the height of which is fifteen feet above the surface of the water, through Saperton hill, two miles and three furlongs in extent, for the purpose of communicating with the Thames at Lechlade. In November 1789, this navigation was completed. The Severn is distinguished for the abundance of salmon which frequent it, and the lamprey, which is almost peculiar to it; this last fish is in season in the spring of the year, when it has a delicious taste, which abates as the summer advances.

The TRENT rises among the moor-lands in the north-west part of Staffordshire, and has its waters increased by several rivulets, by

the Sow, Charnet, Eccleshell-water, and other streams, and then runs to the eastward. It becomes navigable at Burton-upon-Trent, where it leaves this county, and flowing through those of Derby, Nottingham and Lincoln, discharges itself into the Humber, that great receptacle of the northern rivers, running a course of near two hundred miles. It enters Nottinghamshire at the south-west point, where it is joined by the Erwash, and passes to the eastward till it reaches Newark, where it forms an island; when turning to the north, after a track of about fourteen miles, it forms the boundary of that county on the side of Lincolnshire. Poets have derived the name of this river from *thirty* kinds of fishes which are found in it, and from *thirty* streams which flow into it.

> The bounteous Trent, that in himself enseams
> Both thirty sorts of fishes, and thirty sundry streams.

But this ought only to be considered as a poetical fiction. Mr. Pennant determines the name to be Saxon, and says it is derived from its rising from *three* heads. The Dove which rises in the most northern point of Staffordshire, forms the boundary between it and Derbyshire, and joins the Trent a little below Burton. The Sow rises a few miles to the west of Newcastle-under-Line, and falls into the Trent on the south-east. These are well stocked with fishes, especially the Trent. A canal has been formed from Chesterfield, in Derbyshire, which, passing through the northern part of Nottinghamshire, communicates with the Trent just below Gainsborough; it was begun in 1773, and completed in 1775. In its course a subterranean tunnel is cut through Norwood hill, which extends 2850 yards, or upwards of a mile and a half, so perfectly straight, that the termination at one end may be seen at the other, The arch is twelve feet high, nine feet three inches wide, and in the deepest part thirty-six yards below the surface of the earth. By means of the numerous canals which are now formed in the north of England, a communication is opened between the Trent and the Mersey, or quite across the kingdom, from east to west.

The rivers which fall into the HUMBER are the Ouse, or Northern Ouse, and those by which the Ouse itself is enriched, as the Dun, or Don, the Derwent, the Calder, the Aire, the Wharse, the Nidd, the Yore, and the Swale. The Ouse rises in the west-north-

west side of Yorkshire, and chiefly runs to the south-east. The Dun, or Don, rises in the hills near the south-west end of Yorkshire, where it is called the Sheaf, and running to the southward till it has reached Sheffield, turns to the north-east, and falls into the Ouse. The Calder has its source in the edge of Lancashire, and entering the south-west side of Yorkshire, runs eastward, and joins the river Aire. The Aire has its spring at the foot of a high hill, called Pennigent, running slowly, and chiefly to the eastward, discharges itself into the Ouse. The Wharse, or Wherse, rises among the hills in the west of Yorkshire, and runs with a swift and impetuous current, mostly to the south-east, till it falls into the Ouse. The Swale rises among the north-west hills of Yorkshire, and running chiefly to the south east, joins the Nidd, about four miles below Borough-bridge. The Derwent, which divides the north and east ridings, rises in the north-east of Yorkshire, near the sea-coast, between Whitby and Scarborough, and first runs to the south, then winds to the west, and again to the south, falling at length, like the preceding, into the Ouse. The Hull has its source in the Woulds, whence it runs mostly to the southward, passing near Beverley, and falls into the Humber; all these afford abundance of fishes, particularly salmon, trout, and craw-fish. Into each of these rivers a great number of rivulets discharge themselves.

The Humber is formed at the confluence of the Ouse, and may rather be considered as a narrow bay than a river, being throughout its short course extremely wide. Its whole extent, quite to Spurn-head, a narrow peninsular which terminates Yorkshire to the south-eastward, is not more than thirty-six miles. Yorkshire partakes of the advantage derived from that great modern improvement, navigable canals. A communication has been obtained between the western and eastern coasts, across Lancashire and Yorkshire, by means of a canal, proceeding from the river Mersey, at Liverpool, to the Ouse, at Selby, about sixteen miles above its junction with the Humber; the canal is not yet fully completed according to the original plan, but it has been long rendered navigable across the county of York, from Holme-bridge, four miles north-west of Skipton, to the Ouse, passing by Leeds; and by act of parliament the proprietors are enabled to borrow additional sums of money for the purpose of completing the design. From this canal a branch is formed, about three miles in extent, to Bradford. Another of small

Engraved by H.E. Cook, from a Drawing by Craig — *For the Gallery of Nature &c.*

AQUEDUCT OF THE PEAT FOREST CANAL

over the River Mersey.

extent is cut near Wakefield, to facilitate the communication between this place and Halifax.

While speaking of canals, that astonishing work which, under the name of the NEW RIVER, was begun in the early part of the last century, and which in its progress and completion has proved so highly interesting to the most populous and wealthy part of this country, ought not to pass unnoticed.

This most noble undertaking, for the purpose of supplying the northern and western parts of the cities of London and Westminster, and nearly the whole of their environs, with that necessary of life, water, is by means of this river, which is conducted in an artificial canal, extending through a winding course of thirty-eight miles three quarters and sixteen poles, from the springs of Chadwel and Amwell, near Ware, in Hertfordshire. It was undertaken in the year 1606, by Mr. Hugh Middleton, citizen and goldsmith of London, who was afterwards knighted, and at length created a baronet; but the title is now extinct. In about five years he had brought the water as far as Enfield, but having met with great difficulties, and strong opposition, he found himself extremely impoverished by the undertaking, and applied to the lord mayor and corporation of London for assistance, but they refusing to be concerned, he made a more successful application to James I. who, in the year 1612, engaged to bear half the expense of the concern on becoming a half partner in it; though the king was excluded from interfering at all in its management. The sums paid out of the Exchequer at various times, from Easter 1612 to September 1614, in consequence of this covenant, were 6,347*l.* In the following year, water was brought into the bason called "The New River Head," at Islington. It was then thought to be an object worthy of national attention, and Sir Hugh Middleton dividing his moiety into thirty-six shares, sold twenty-nine of them. It was not, however, until the year 1633 that any dividend of profit was made, and Sir Hugh died in the year 1631; the proportion to each twenty-ninth share was, at that time, 11*l.* 19*s.* 1*d.* the second dividend was only 3*l.* 4*s.* 2*d.* and instead of a third, a call upon the partners was expected to be made. Charles I. supposing little advantage would accrue from the undertaking, re-conveyed to Sir Hugh Middleton, in his life-time, the royal moiety, on condition of having secured to him and his successors a fee-farm rent of 500*l.* per annum. This moiety was like-

wise divided into thirty-six shares, which were called "the king's shares," as the other twenty-nine were; "the adventurers," who were incorporated by letters patent, in the year 1619, by the name of "The New River Company," and the government of the concern lodged in their hands, In the year 1766, one of the king's shares was sold by public auction for 4,400*l.* and in 1770, another king's share, or one seventy second part of the whole, was purchased at a public auction for 6,700*l.* The corporation consists of a governor, deputy-governor, treasurer, and twenty-six directors, a collector and his assistant, a surveyor and his deputy, collectors, and workmen. The canal called "The New River" is carried over two vales, in wooden frames, or troughs, lined with lead; in its course are forty-three sluices, and over it are two hundred and fifteen bridges. In some parts it is conveyed through subterranean passages.

Sir Hugh Middleton left by his will some of his shares to the Goldsmiths' company, to be divided among its poor members.

This adventurous baronet was possessed of mines in Cardiganshire, which he is said to have worked to so great advantage, as to have cleared two thousand pounds a month for several years together, which enabled him to bring the New River water to London; but Mr. Pennant says that he expended the whole on that great object, and was so reduced, as to support himself by becoming an hireling surveyor. One of his female descendants, being in very reduced circumstances, was, not many years ago, voted a small annuity by the corporation of London, in consequence of a petition which she presented.

NORTH AMERICA.

America is extremely well watered by rivers not only for the support of animal life, and all the advantages of fertility, but for the convenience of trade, and the intercourse of the distant inhabitants by water. In North America, the great river MISSISSIPPI runs chiefly from north to south, receiving in its course many large rivers, scarcely inferior to the Rhine or the Danube, navigable almost from their sources, and laying open the inmost recesses of this part of the continent. Near the heads of these are extensive lakes of fresh water, which have a communication with

each other, and with the great river ST. LAWRENCE. On the eastern side of North America are the fine rivers, HUDSON, DELAWARE, JAMES, POTOWMACK, SUSQUEHANNA, CONNECTICUT, and several others of extensive length and depth.

The rivers which flow westward, and discharge themselves into the Pacific Ocean are very imperfectly known; among these, the OREGAN, COLUMBIA, or RIVER OF THE WEST, is probably by far the largest. Captain Cook proceeded a considerable way up it in the year 1778, and through the whole extent of his navigation it was found to be broad, deep, and rapid, so that it may be supposed to take its rise in the central part of the American continent.

The BOURBON has only been traced from a very extensive lake, which has received the same name; its course is toward Hudson's bay, above the fifty-fifth degree of north latitude.

The vast river MISSISSIPPI is supposed to take its rise from three or four springs, which unite at about 46° north latitude, and 98° west longitude; it has been ascended as high as 45° north, about one hundred and fifty miles above the *Falls of St. Anthony*. Its course extends above two thousand miles, comprising its continual flexions. It proceeds in a south-east direction, till it arrives at about 35° north latitude, and then proceeds almost due south, till it arrives at West Florida, where it again runs to the south-east.

It receives the river St. Pierre, or St. Peter, on the westward, near the Falls of St. Anthony, and the Moingona in the same direction, about 41° north latitude; from the eastward, the Fox river; and the Illinois below 40°. A little lower, the noble Missouri runs into it from the westward; the Ohio joins it from the eastward. At 33°, the White river and the Paniassas first join, and then pour their united streams into this grand receptacle of waters, which discharges itself into the sea by many openings, most of which have but little depth of water.

The Mississippi, after being joined by the Missouri, is about six miles wide, and continues its course southerly, no considerable stream falling into it after this for between two and three hundred miles, when it is joined by the Ohio. The country on each side the Mississippi to this place is exceedingly fine, the climate warm and agreeable.

The navigation of the Mississippi is very tedious, even in descending, as it is not deemed safe to sail down it during the night; the

river being constantly encumbered with floating trees, which the winds tear from its banks, and precipitate into the water. The ascent is still more difficult and tedious. Proceeding northward from its mouth, the adjacent country is one continued level spot, covered with vast forests of trees, which so entirely intercept the winds, as to cause a dead calm constantly to prevail, so that in this part it commonly takes a month to sail only twenty leagues. When these forests cease, the remainder of the navigation is obstructed by strong currents, so that boats seldom advance farther than five or six leagues in a whole day. This river bounds Louisiana to the eastward.

The OHIO, or Fair River, which Mr. Jefferson calls "the most beautiful river upon earth," rises in several branches, some of which spring near lake Erie, and others within a few miles of lake Ontario. It is called the Alleghany, until it is joined by the Monongahela, which rises from the west side of the Alleghany mountains, in a great number of small streams, that unite, and, together with the Alleghany, form this river, about 40° 35′ north latitude, when it takes the name of Ohio. Its general course afterward inclines to the south-west, and takes a remarkably winding serpentine form. At Fort Pitt, where the junction is made, it is a mile wide, but grows much wider before it joins the ississippi, which is in latitude 36° 8′ north, receiving several streams in its course thither.

The country between the lakes and the junction of the Ohio and Mississippi, for several hundred miles, is level, and has an excellent soil; the climate is healthy and agreeable, and the winters short and moderate: its natural productions are numerous and valuable: it is well stocked, but not encumbered with timber trees, so that no country in the world is capable of nobler improvements.

Great part of this country is now settled, and new states are forming; of these *Kentuckey* has for many years sent representatives and senators to congress.

None of these American rivers are acted upon by tides, the copious efflux causing the waters constantly to proceed with rapidity toward the mouth, so that no ships, without great difficulty, can proceed upward in any of these rivers, and the commercial benefits which they yield are chiefly internal, furnishing a ready conveyance for the productions of the country, but incapable of bringing back any foreign articles. In the rising state of Kentuckey many ships are built, which floating down the Ohio, proceed to the gulf of

Mexico, and taking the benefit of the current, which constantly sets in to the northward through the Bahama straits, arrive at their destined port on the eastern coast of North America, with greater celerity and safety. One material impediment, however, to this navigation on the Ohio, is a considerable fall, about the latitude of 38° north. Its descent, however, is gradual, but continued for half a league: the breadth of the river in that part is a mile and a quarter. The level of the river by this fall is not sunk more than twenty feet. There is a considerable variation in the quantity of water which fills the bed of this river at different seasons of the year, and when the river becomes shallow, the depth of water at this fall is only sufficient to convey light boats down the stream.

The ISLE OF ORLEANS, at the mouth of the Mississippi, in 29° 58′ latitude, and 89° 59′ west longitude from Greenwich, is a very beautiful and fertile spot of ground, on which the French had a considerable city, named *New Orleans*, which is the capital, and indeed the only city of Louisiana. It is fortified in a regular manner, and according to some French authors, has about six hundred handsome houses, and five parish churches, with straight and handsome streets, that cross each other at right angles, but the buildings are chiefly of wood, and not remarkable for their beauty.

This town owed its rise to the delusions which were practised by the celebrated projector Law upon the French nation. The immense wealth which was supposed to be contained in the mines of *St. Barbe*, in Louisiana, caused a company to be formed in France, and a national phrenzy long prevailing, vast numbers embarked for the purpose of settling on the banks of the Mississippi. They were landed at Biloxi, in West Florida, where the far greater number perished by want and misfortunes. Five years afterwards, the survivors were removed to the island on which the town of New Orleans was built, and so named after the regent of France. The Abbé Raynal asserts that upwards of a million sterling was sunk in this disastrous scheme.

The source of the ST. LAWRENCE, the great river of Canada, has never been traced, though it is known to have a communication with the lakes into the interior country to a vast extent. *Carver*, indeed, asserts, that the four capital rivers on the continent of *North America*, viz. the *St. Lawrence*, *Mississippi*, *Bourbon*, and *Oregan*, or river of the west, have their sources very near each other: those of the three former being within thirty miles, the latter some-

what farther to the west; but the evidence on which he makes this assertion is by no means clear and conclusive. After a north-eastern course of many hundred miles, it discharges its waters into a large gulf, extending from 45° 30′ to 51° north latitude; the islands of Newfoundland and Cape Breton lying between it and the great Atlantic Ocean. The river is navigable for large ships as high as Quebec, which is four hundred miles from its mouth; farther up, shoals and rocks impede its navigation. The French, while in possession of Canada, industriously exaggerated the difficulties and dangers attending the navigation of this river; but since the English have possessed the country, the utmost attention has been bestowed to form accurate charts of it, and to give every kind of assistance for its safe navigation. In executing these designs, Captain Cook was for some time employed, before he became a circumnavigator, in performing which his great abilities were first discovered, and the foundation laid for his future fame.

HUDSON'S, or the NORTH RIVER, rises within about twenty miles of *Lake George*, and runs to the south, discharging itself at New York, or Sandy Hook. This river is navigable for vessels of one hundred tons, as high as Albany, which is a course of one hundred and fifty miles, and shallops may go up eight or ten miles higher.

The largest river in the state of Pennsylvania is the DELAWARE, which rises in the country of the Five Nations, and flows into the sea at Delaware-bay. It is navigable for near an hundred and fifty miles up, after which it has some falls; the settlements upon this river extend an hundred and fifty miles from the city of Philadelphia, which is seated on its banks to the westward, and on the Schoolkill to the eastward, which it joins a few miles below Philadelphia. The lands on the banks of the Delaware are excellent. Its course is nearly south-east, and it affords great plenty of all such fishes as are common to the climate, especially sturgeon, which are here cured, and exported in greater abundance than in any other part of America.

The SUSQUEHANNA rises in the same country, at the distance of ninety miles from the Apalachian mountains, and runs at first south-west, and then south-east, nearly parallel to the Delaware, till it discharges itself into Chesapeak-bay, in Maryland. This river is likewise navigable a great way up the interior country, and, if possible, exceeds the other in the pleasantness and fertility of the soil

on its banks, which produces, in great abundance, all sorts of corn, especially wheat.

The *Schoolkill*, or *Skulkill*, has its source in the same country, running almost parallel to the two other rivers, till at length it falls into the Delaware, near the city of Philadelphia, above which it is navigable for boats, at least a hundred miles higher up the country.

These rivers, with the numerous bays and creeks in Delaware bay, capable of containing the largest fleets, render this province admirably suited for carrying on a foreign trade. The country also abounds in streams fit for mills, and all other kinds of mechanical expedients for easing the labour of man; hence there is here manufactured a greater quantity of iron than in any province on the continent.

The bay of Chesapeak is one of the largest and safest bays perhaps in the world; for it enters the country near three hundred miles from the south to the north, having the eastern side of Maryland, and a small part of Virginia, on the same peninsula, to cover it from the Atlantic Ocean. This bay is almost eighteen miles broad for a considerable way, and seven where it is narrowest, the water in most places being nine fathom deep. Through its whole extent it is enriched, both on the eastern and western side, by a vast number of fine navigable rivers: for, beside those of Maryland, it receives from the side of Virginia, James-river, York-river, the Rappahanock, and the Potowmac.

These rivers are not only navigable themselves for very large vessels a considerable way into the country, but have so many creeks, and receive such a number of smaller navigable rivers, as render the communication of all parts of this country inconceivably more easy than that of any other. The Potowmac is navigable for near two hundred miles; it is nine miles broad at its mouth, and for a vast way not less than seven. The other three are navigable upward of eighty; and in the windings of their several courses approach one another so nearly, that the distance between them is in some parts not more than ten, and in others not more than five miles; while in others again there are fifty miles between each of them. The planters, as in Maryland, load and unload vessels of great burden at their own doors; which, as their commodities are of small value in proportion to their bulk, is an incalculable convenience.

CONNECTICUT river rises in New Hampshire state, latitude 45° 10′; it pursues a remarkably straight course to the south, and dis-

charges its waters into the sound opposite to Long Island. About one hundred and forty miles from its source, near the town of Walpole, are very rapid falls, the force of which is caused by the water's being enclosed by two rocks within a space of about thirty feet, and falling into a broad bason below. Over these rocks a bridge was constructed in 1784, with such an elevation as to be inaccessible to the highest floods. From these falls to the mouth of the river the distance is about one hundred and sixty miles.

SOUTH AMERICA.

We have yet to describe three majestic floods, that may well vie with any we have yet glanced at. These are, the *Oronooko*, or Orinoko, the *River* of *Amazons*, sometimes called the *Orellana*, but more properly the *Maragnon*; and the *Plate River*, or *Rio de la Plata*. They all run in the general direction of from west to east.

The ORONOOKO forms one boundary for Guiana. It is said to be seven hundred and fifty-five leagues in length, from its source, in Popayan, near the Pacific Ocean, to its discharge into the Atlantic, in 9° north latitude, where its impetuosity is so great, that it stems the most powerful tides, and preserves the freshness of its waters to the distance of twelve leagues out at sea. The Oronooko in the month of April begins to swell, and continues to rise during five months; the sixth it remains at its greatest height; in October it begins to subside, and falls gradually until the month of March; during which month it remains at a fixed state of its utmost diminution. This regular rise and fall of its waters is unquestionably produced by the rainy and the dry seasons, which alternately prevail in this part of the world.

Columbus, in his third voyage of discovery, which commenced on the 30th of May, 1498, taking a more southern course than he had pursued in his two former voyages, discovered the island of Trinidad, on the coast of Guiana, near the mouth of this great river, on the first of August following. The swell occasioned by its waters pouring into the ocean was so great as to expose the ships to extreme danger, but after long combating the currents and tremendous waves with doubtful success, he conducted his squadron safe through a narrow strait, which separates that island from the continent; this

he called "*Bocca del Drago*," the dragon's mouth. He justly concluded that such a vast body of water must flow through a country of immense extent, and that he was now arrived at that continent which it had long been the object of his wishes to discover. Full of this idea, he stood to the west, along the coast of those provinces now known by the names of Paria and Comana.

The Oronooko, though a river only of the third or fourth magnitude in the new world, far surpasses the largest rivers in our hemisphere. It rolls toward the ocean such a vast body of water, and rushes into it with such impetuous force, that when it meets the tide, which on that coast rises to an uncommon height, their collision occasions a swell and agitation of the waters no less surprising than formidable.

The RIVER of the AMAZONS, which is the northern boundary of Brasil, as it has its source among the Andes, which are the highest mountains on the globe, is the greatest river in the world. Its rise is not far from the Pacific Ocean, and it runs in an eastern course, according to Ulloa and Condamine, more than twelve hundred leagues, in which progress it received above sixty considerable rivers. In some parts it divides into several branches, encompassing a multitude of islands, and at length discharges itself into the Atlantic Ocean, directly under the equinoctial line, by a channel one hundred and fifty miles broad.

The first European who sailed down the river of Amazons, or as it is more properly called the *Maragnon*, was Francis Orellana, soon after the conquest of Peru, in the year 1541. He was next in command to Gonzalo Pizarro, the governor of Quito, and a brother of that heinous barbarian who slaughtered or enslaved the Peruvians, alike regardless of every restraint from the calls of justice, as insensible to the feelings of humanity. Gonzalo Pizarro, with a body of Spanish soldiers, and some thousand Indians, attempted to penetrate into the interior recesses of the American continent, expecting to acquire great wealth in countries possessed by other tribes of Indians; but in his whole progress, neither inhabitants, nor silver, nor gold, supplied him and his followers with their expected prey: but a fate more merited pursued them; for they encountered such hardships from incessant rains, want of subsistence, and continual exertions in cutting their way through thick woods, or wading through marshes and morasses, that great numbers of the party perished miserably;

at length, the survivors reached the Coca or Napo, one of the large rivers whose waters pour into the Maragnon, and contribute to its grandeur. There a bark was built, and fifty soldiers, under the command of Orellana, proceeded in it down the stream, sent by Pizarro to procure food for their perishing associates; but no principle of honour, or emotion of pity, could actuate such men; Orellana, regardless of their situation whom he had left on shore, determined to abandon them to their fate, to follow the course of the stream, and explore the countries through which it passed.

Pizarro had no suspicion of the treachery of his officer until he learnt the fatal tidings by one of the fifty in the bark, and this man had been landed on a desert shore, there to perish, because he expressed his abhorrence of such a cruel breach of trust: Pizarro having proceeded onward, happening to reach the spot, and hearing the dreadful tidings, immediately attempted to return to Quito, which was at the distance of twelve hundred miles. In this desponding rout hunger compelled them to feed on roots and berries, and even to gnaw the leather of their saddles and sword-belts. Four thousand Indians and two hundred and ten Spaniards perished in this wild, disastrous expedition, which continued near two years; and only fourscore got back to Quito, naked as savages, and so emaciated by famine and fatigue, that they appeared more like spectres than men.

Of Orellana's enterprise, Dr. Robertson speaks as follows. "This scheme of Orellana's was as bold as it was treacherous. For, if he be chargeable with the guilt of having violated his duty to his commander, and with having abandoned his fellow-soldiers in a pathless desert, where they had hardly any hopes of success, or even of safety, but what were founded on the service which they expected from the bark; his crime is, in some measure, balanced by the glory of having ventured upon a navigation of near two thousand leagues, through unknown nations, in a vessel hastily constructed, with green timber, and by very unskillful hands, without provisions, without a compass, or a pilot. But his courage and alacrity supplied every defect. Committing himself fearlessly to the guidance of the stream, the Napo bore him along to the south, until he reached the great channel of the Maragnon. Turning with it toward the coast, he held on his course in that direction. He made frequent descents on both sides of the river, sometimes seizing by force of arms the provisions of the fierce savages seated on its banks; and sometimes pro-

curing a supply of food by a friendly intercourse with more gentle tribes. After a long series of dangers, which he encountered with amazing fortitude, and of distresses which he supported with no less magnanimity, he reached the ocean, where new perils awaited him. These he likewise surmounted, and got safe to the Spanish settlement in the island of Cubagua; thence he sailed to Spain. The vanity natural to travellers who visit regions unknown to the rest of mankind, and the art of an adventurer, solicitous to magnify his own merit, concured in prompting him to mingle an extraordinary proportion of the marvellous in the narrative of his voyage. He pretended to have discovered nations so rich, that the roofs of their temples were covered with plates of gold; and described a republic of women, so warlike and powerful, as to have extended their dominion over a considerable tract of the fertile plains which he had visited. Extravagant as those tales were, they gave rise to an opinion that a region abounding with gold, distinguished by the name of El Dorado, and a community of Amazons, were to be found in this part of the New World; and such is the propensity of mankind to believe what is wonderful, that it has been slowly and with difficulty that reason and observation have exploded those fables. The voyage, however, even when stripped of every romantic embellishment, deserves to be recorded, not only as one of the most memorable occurrences in that adventurous age, but as the first event which led to any certain knowledge of the extensive countries that stretch eastward from the Andes to the ocean."

Herrera, in his History of America, gives a circumstantial account of Orellana's voyage. It appears that he was very near seven months from the time of his embarking to his reaching the mouth of the river.

M. de la Condamine, in the year 1743, for the purpose of measuring a degree of the meridian, sailed from Cuenca to Para, a settlement of the Portuguese at the mouth of the river, a navigation much longer than that of Orellana, in less than four months. But the two adventurers were very differently provided for the voyage. This hazardous undertaking, to which ambition prompted Orellana, and the love of science M. de la Condamine, was undertaken by Madam Godin des Odonais, in the year 1769, from conjugal affection. The narrative of the hardships which she suffered, of the dangers to which she was exposed, and of the disasters which befel her is one of the most singular and affecting stories related in any

language, and exhibit in her conduct a striking picture of the fortitude which distinguishes the one sex, mingled with the sensibility and tenderness peculiar to the other.

The early Spanish writers have given to this river the name of the man who first descended it.

The Rio de la Plata, or River of Plate, rises likewise among the mountains on the western side of South America; its course is said to be more than eight hundred leagues, in which it receives above fifty rivers; it discharges itself into the Atlantic Ocean by a very extensive mouth, its northern coast being in 35°, and its southern in 36° 20′ south latitude.

This vast river was first discovered by John Diaz de Solis, whom Ferdinand of Spain had fitted out at his own expense, in the year 1515, and provided with two ships for the purpose of opening a communication with the Moluccas, or Spice Islands, by the west. De Solis was considered as one of the most skilful navigators in Spain. On the 1st January, 1716, he entered a river which he called Janeiro. He proceeded thence to a spacious bay, which he supposed to be the entrance into a strait that communicated with the Indian Ocean; but on advancing farther, he found it to be the mouth of *Rio de la Plata*. In endeavouring to make a descent in the country, De Solis and several of his crew were slain by the natives, who, in sight of the ships, cut their bodies in pieces, roasted and devoured them. Discouraged by the loss of their commander, and terrified at this shocking spectacle, the surviving Spaniards set sail for Europe, without attempting any discovery, and nothing farther was heard of it until several years afterward, when the Portuguese gained a knowledge of its amazing extent.

P. Cataneo, a Modenese Jesuit, who landed at Buenos Ayres in the year 1749, represents his astonishment at viewing this vast body of water in the following manner. "While I resided in Europe," says he, "and read in books of history or geography that the mouth of the river De la Plata was a hundred and fifty miles in breadth, I considered it as an exaggeration, because in this hemisphere we have no example of such vast rivers. When I approached its mouth, I had the most vehement desire to ascertain the truth with my own eyes; and I have found the matter to be exactly as it was represented. This I deduce particularly from one circumstance: When we took our departure from Monte-Video, a fort situated more than a hun-

dred miles from the mouth of the river, and where its breath is considerably diminished, we sailed a complete day before we discovered the land on the opposite bank of the river; and when we were in the middle of the channel, we could not discern land on either side, and saw nothing but the sky and water, as if we had been in some great ocean. Indeed, we should have taken it to be sea, if the freshness of its water, which was turbid like the Po, had not satisfied us that it was a river. Moreover, at Buenos Ayres, another hundred miles up the river, and where it is still much narrower, it is not only impossible to discern the opposite coast, which is indeed very low and flat; but one cannot perceive the houses, or the tops of the steeples, in the Portugueze settlement at Colonia, on the other side of the river."

The number of the different sorts of fish in the rivers of South America is so extraordinary, as to merit particular notice. "In the Maragnon," says P. Acugna, "they are so plentiful, that, without any art, one may take them with the hands." "In the Orinoco," says P. Gumilla, "beside an infinite variety of other fishes, tortoise or turtle abound in such numbers, that I cannot find words to express them. I doubt not then that such as read my account will accuse me of exaggeration: but I can affirm, that it is as difficult to count them, as to count the sands on the banks of that river. One may judge of their multitude by the amazing consumption of them; for all the nations contiguous to the river, and even many who are at a distance, flock thither at the season of breeding, and not only find sustenance during that time, but carry off great numbers both of the turtles and of their eggs, &c."

It has been asserted, that most of the rivers in Peru and Chili have scarce any motion by night, while upon the appearance of the morning sun, they resume their former rapidity: this proceeds from the mountain snows, which melting with the heat, increase the stream, and continue to drive on the current, whilst the sun continues to dissolve them. These wonderful masses of water have been thus ably and elegantly described by the poet of the Seasons:—

> Nor less thy world, Columbus, drinks refresh'd
> The lavish moisture of the melting year.
> Wide o'er his isles, the branching Oronoque
> Rolls a brown deluge; and the native drives

To dwell aloft on life-sufficing trees,
At once his dome, his robe, his food, and arms.
Swell'd by a thousand streams, impetuous hurl'd
From all the roaring Andes, huge descends
The mighty Orellana. Scarce the muse
Dares stretch her wing o'er his enormous mass
Of rushing water; scarce she dares attempt
The sea-like Plata; to whose dread expanse
Continuous depth, and wondrous length of course,
Our floods are rills. With unabated force,
In silent dignity they sweep along,
And traverse realms unknown, and blooming wilds,
And fruitful deserts, worlds of solitude,
Where the sun shines, and seasons teem in vain,
Unseen and unenjoy'd. Forsaking these,
O'er peopled plains they far diffusive flow,
And many a nation feed, and circle safe,
In their soft bosom, many a happy isle;
The seat of blameless Pan, yet undisturb'd
By christian crimes and Europe's cruel sons.
Thus pouring on they proudly seek the deep,
Whose vanquish'd tide, recoiling from the shock,
Yields to this liquid weight of half the globe;
And Ocean trembles for his green domain.

[*Labat, Lobo, Swinburne, Camden, Raynal, Carver, Robertson, Condamine, Herrera.*]

SECTION III.

CLASSICAL, OR PICTURESQUE SPRINGS, LAKES, RIVERS, AND CASCADES, DESCRIBED BY CLASSICAL AUTHORS.

1. *Source of the Scamander, the Mender of the present day.*

On the eleventh of March, having collected our guides and horses as upon the preceding day, we set out again from Evgillar, and proceeded up the mountain, to visit the Cataract, which constitutes the source of the Mender, on the north-west side of Gargarus. Ascending by the side of its clear and impetuous torrent, we reached, in an hour and a half, the lower boundary of the woody region of the mountain. Here we saw a more entire chapel than either of those described in our excursion the preceding day, situated upon an eminence above the river. Its form was quadrangular,

and oblong. The four walls were yet standing, and part of the roof: this was vaulted, and lined with painted stucco. The altar also remained, in an arched recess of the eastern extremity: upon the north side of it was a small and low niche, containing a marble table. In the arched recess was also a very antient painting of the Virgin; and below, upon her left hand, the whole length portrait of a Saint, holding an open volume. The heads of these figures were encircled by a line of Glory. Upon the right-hand side of the Virgin there had been a similar painting of some other Saint, but part of the stucco, whereon it was painted, no longer remained. The word ΠΑΡΘΕΝΟΝ, written among other indistinct characters, appeared upon the wall. The dimensions of this building were only sixteen feet by eight. Its height was not quite twelve feet, from the floor to the beginning of the vaulted roof. Two small windows commanded a view of the river, and a third was placed near the altar. Its walls, only two feet four inches in thickness, afforded, nevertheless, space for the roots of two very large fir-trees; these were actually growing upon them. All along the banks of this river, as we advanced towards its source, we noticed appearances of similar ruins; and in some places, among rocks, or by the sides of precipices, were seen remains of several habitations together; as if the monks, who retreated hither, had possessed considerable settlements in the solitudes of the mountain. Our ascent, as we drew near to the source of the river, became steep and stony. Lofty summits towered above us, in the greatest style of Alpine grandeur; the torrent, in its rugged bed below, all the while foaming upon our left. Presently we entered one of the sublimest natural amphitheatres the eye ever beheld; and here the guides desired us to alight. The noise of waters silenced every other sound. Huge craggy rocks rose perpendicularly, to an immense height; whose sides and fissures, to the very clouds, concealing their tops, were covered with pines; growing in every possible direction, among a variety of evergreen shrubs, wild sage, hanging ivy, moss, and creeping herbage. Enormous plane-trees waved their vast branches above the torrent. As we approached its deep gulph, we beheld several cascades, all of foam, pouring impetuously from chasms in the naked face of a perpendicular rock. It is said the same magnificent cataract continues during all seasons of the year, wholly unaffected by the casualties of rain or melting snow. That a river so

ennobled by antient history should at the same time prove equally eminent in circumstances of natural dignity, is a fact worthy of being related. Its origin is not like the source of ordinary streams, obscure and uncertain; of doubtful locality and indeterminate character; ascertained with difficulty, among various petty subdivisions, in swampy places, or amidst insignificant rivulets, falling from different parts of the same mountain, and equally tributary; it bursts at once from the dark womb of its parent, in all the greatness of the divine origin assigned to it by Homer.* The early Christians, who retired or fled from the haunts of society to the wilderness of Gargarus, seem to have been fully sensible of the effect produced by grand objects, in selecting, as the place of their abode, the scenery near the source of the Scamander; where the voice of nature speaks in her most awful tone; where, amidst roaring waters, waving forests, and broken precipices, the mind of man becomes impressed, as by the influence of a present Deity.†

The course of the river, after it thus emerges, with very little variation, is nearly from east to west. Its source is distant from Evgillar about nine miles; or, according to the mode of computation in the country, three hours; half this time is spent in a gradual ascent from the village. The rock whence it issues consists of micaceous schistus, containing veins of soft marble. While the artist was employed in making drawings, ill calculated to afford adequate ideas of the grandeur of the scenery, I climbed the rocks, with my companions, to examine more closely the nature of the chasms whence the torrent issues. Having reached these, we found, in their front, a beautiful natural bason, six or eight feet deep, serving as a reservoir for the water in the first moments of its emission. It was so clear, that the minutest object might be discerned at the bottom. The copious overflowing of this reservoir causes the appearance, to a spectator below, of different cascades, falling to the depth of about forty feet; but there is only one source. Behind are the chasms whence the water issues. We entered one of these,

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* Iliad. Φ. I.

† Præsentiorem et conspicimus Deum,
Per invias rupes, fera per juga,
Clivosque præruptos, sonantes
Inter aquas, memorumque noctem!

and passed into a cavern. Here the water appeared, rushing with great force, beneath the rock, towards the bason on the outside. It was the coldest spring we had found in the country; the mercury in the thermometer falling, in two minutes, to thirty-four, according to the scale of Fahrenheit. When placed in the reservoir immediately above the fall, where the water was more exposed to the atmosphere, its temperature was three degrees higher. The whole rock about the source is covered with moss. Close to the bason grew hazel and plane trees; above were oaks and pines; all beyond was a naked and fearful precipice.

[*Clarke's Travels*, Part II. Sect. 1.]

2. *Source of the Clitumnus.*

From PLINY to ROMANUS.

HAVE you ever seen the source of the river Clitumnus*? as I never heard you mention it, I imagine not: let me therefore advise you to do so immediately. It is but lately indeed I had that pleasure, and I condemn myself for not having seen it sooner. At the foot of a little hill covered with venerable and shady cypress trees, a spring issues out, which gushing in different and unequal streams forms itself, after several windings, into a spacious bason, so extremely clear that you may see the pebbles and the little pieces of money which are thrown into it †, as they lie at the bottom. From thence it is carried off not so much by the declivity of the ground, as by its own strength and fulness. It is navigable almost as soon

* Now called Clitumno: it rises a little below the village of Campello in Ombria. The inhabitants near this river still retain a notion that its waters are attended with a supernatural property, imagining it makes the cattle white that drink of it: a quality for which it is likewise celebrated by many of the Latin poets. See Addison's Travels.

† The heads of considerable rivers, hot springs, large bodies of standing water, &c. were esteemed holy among the Romans, and cultivated with religious ceremonies. "Magnorum fluminum," says Seneca, "Capita reveremur; subita et ex abdito vasti amnis eruptio æras habet: coluntur aquarum calentium fontes; et stagna quædam, vel opacitas, vel immensa altitudo sacravit." Ep. 41. It was customary to throw little pieces of money into those fountains, lakes, &c. which had the reputation of being sacred, as a mark of veneration for those places, and to render the presiding deities propitious. Suetonius mentions this practice in the annual vows which he says the Roman people made for the health of Augustus.

as it has quitted its source, and wide enough to admit a free passage for vessels to pass by each other, as they sail with or against the stream. The current runs so strong, though the ground is level, that the large barges which go down the river have no occasion to make use of their oars; while those which ascend find it difficult to advance, even with the assistance of oars and poles; and this vicissitude of labour and ease is exceedingly amusing when one sails up and down merely for pleasure. The banks on each side are shaded with the verdure of great numbers of ash and poplar trees, as clearly and distinctly seen in the stream, as if they were actually sunk in it. The water is cold as snow, and as white too. Near it stands an ancient and venerable temple, wherein is placed the river-god Clitumnus, clothed in a robe, whose immediate presence the prophetic oracles here delivered sufficiently testifiy. Several little chapels are scattered round, dedicated to particular gods, distinguished by different names, and some of them too presiding over different fountains. For, besides the principal one, which is as it were the parent of all the rest, there are several other lesser streams, which, taking their rise from various sources, lose themselves in the river: over which a bridge is built, that separates the sacred part from that which lies open to common use. Vessels are allowed to come above this bridge, but no person is permitted to swim except below it*. The Hispalletes †, to whom Augustus gave this place, furnish a public bath, and likewise entertain all strangers at their own expense. Several villas, attracted by the beauty of this river, are situated upon its borders. In short, every object that presents itself will afford you entertainment. You may also amuse yourself with numberless inscriptions, that are fixed upon the pillars and walls by different persons, celebrating the virtues of the fountain, and the divinity that presides over it. There are many of them you will greatly admire, as there are some that will make you laugh; but I must correct myself when I say so; you are too humane, I know, to laugh upon such an occasion. Farewell.

[*Melmoth's Translation.*]

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* The touch of a naked body was thought to pollute these consecrated waters, as appears from a passage in Tacitus, l. 14. an. c. 22.

† Inhabitants of a town in Ombria, now called Spello.

The Lake Vadimon.

PLINY to GALLUS.

THOSE works of art or nature, which are usually the motives of our travels, are often overlooked and neglected if they happen to lie within our reach; whether it be that we are naturally less inquisitive concerning those things which are near us, while our curiosity is excited by remote objects; or because the easiness of gratifying a desire is always sure to damp it; or, perhaps, that we defer, from time to time, viewing what we know we have an opportunity of seeing whenever we please. Be the reason what it may, it is certain there are several rarities in and near Rome, which we not only have never seen, but have never so much as heard of; and yet, if they had been the production of Greece, or Egypt, or Asia, or any other country which we admire as fruitful in wonders, they would, long since, have been the subjects both of our reading, conversation, and inspection. For myself, at least, I confess I have lately been entertained with a sight of one of these our indigenous singularities, to which I was an entire stranger before. My wife's grandfather desired I would look upon his estate near Ameria *. As I was walking over his grounds, I was shown a lake that lies below them, called Vadimon †, which I was informed had several very extraordinary qualities attending it. This raised my curiosity to take a nearer view. Its form is exactly circular; there is not the least obliquity or winding; but all is regular and even, as if it had been hollowed and cut out by the hand of art. The water is of a clear sky blue, though with somewhat of a greenish cast; it seems, by its taste and smell, impregnated with sulphur, and is deemed of great efficacy in all fractures of the limbs, which it is supposed to consolidate. Notwithstanding it is but of a moderate extent, yet the winds have a great effect upon it, frequently throwing it into violent commotions. No vessels are suffered to sail here, as its waters are held sacred ‡, but several floating islands § swim about in it, covered with reeds

* Now called Amelia, an episcopal city in Ombria.

† Now called Lago di Bassanello.

‡ See note p. 53.

§ The credit of this account does not rest entirely upon our author: Pliny the elder mentions these floating islands, (l. 2. 95.) and so does Seneca, who accounts for them upon philosophical principles. (Q. N. l. 3. 25.) Varenius says, that in Honduras, a province in America, there is a lake in which are several

and rushes, together with other plants, which the neighbouring marsh and the borders of the lake produce. These islands differ in their size and shape; but the edges of all of them are worn away by their frequent collision against the shore and each other. They have all of them the same height and motion, and their respective roots, which are formed like the keel of a boat, may be seen hanging down in the water, on which ever side you stand. Sometimes they move in a cluster, and seem to form one entire little continent; sometimes they are dispersed into different quarters by the winds; at other times, when it is calm, they float up and down separately. You may frequently see one of the larger islands sailing along with a lesser joined to it, like a ship with its long boat: or, perhaps, seeming to strive which shall out-swim the other: then again they all assemble in one station, and afterwards joining themselves to the shore, sometimes on one side, and sometimes on the other, cause the lake to appear considerably less, till at last uniting in the centre, they restore it to its usual size. The sheep which graze upon the borders of this lake, frequently go upon these islands to feed, without perceiving that they have left the shore, till they are alarmed by finding themselves surrounded with water; and in the same manner, when the wind drives them back again, they return, without being sensible that they are landed. This lake empties itself into a river, which, after running a little way, sinks under ground; and if any thing is thrown in, brings it up again where the stream emerges. I have given you this account, because I imagined it would not be less new, nor less agreeable to you than it was to me; as I know you take the same pleasure as myself, in contemplating the works of nature. Farewell.

Baiæ and the Lucrine Lake.

I RETURNED in the morning to the coast of Bauli, where some ruins are shown as the tomb of Agrippina the younger, murdered near this place by order of her son. It is true that her slaves burnt

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little hills planted with shrubs, &c. tossed up and down by the winds. And he quotes Boethius, the Scots historian, who affirms, that, in a large *Loch*, called *Lomond Loch*, in Scotland, there is a floating island, upon which cattle graze. See *Varen. Geog.* Vol. I. p. 413.

her body and deposited the ashes on the road to Bauli; but these ruins bear a greater resemblance to a theatre, or hanging garden, than to a sepulchre. The place of her interment is not to be ascertained, for the sea must now cover a large portion of land which formerly contained spacious gardens, fish-ponds, and buildings: Hortensius, the contemporary and rival of Cicero, possessed a villa on this shore, for which the present confined spot could not possibly afford sufficient space. We next entereda bay, where the placid waters reflect the mutilated remnants of Baiæ, that center of pleasures, that elegant resort of the gay masters of the world. The hot springs and medicinal vapours that abound in its environs must very early have excited the attention of valetudinarians, as bathing was the constant solace of the Greeks while in health, and their remedy when diseased; but Baiæ does not seem to have attained a degree of celebrity superior to that of other baths, till the Roman commonwealth began to be in the wane. As soon as the plunder of a conquered world was transferred from works of public use and ornament to private luxury, the transcendent advantages which Baiæ offered to Roman voluptuaries, flying from the capital in search of health and pleasure, were attended to with enthusiasm: the variety of its natural baths, the softness of its climate, and the beauties of its landscape, captivated the minds of opulent nobles, whose passion for bathing knew no bounds: abundance of linen and disuse of ointments render the practice less necessary in modern life; but the ancients performed no exercise, engaged in no study, without previous ablutions, which at Rome required an enormous expence in aqueducts, stoves, attendants: a place, therefore, where waters naturally heated to every degree of warmth bubbled spontaneously out of the ground, in the pleasantest of all situations, was such a treasure as could not be overlooked. Baiæ was this place in the highest perfection; its easy communication with Rome was also a point of great weight. Hither at first retired for a temporary relaxation the mighty rulers of the empire, to string anew their nerves and revive their spirits, fatigued with bloody campaigns and civil contests. Their habitations were small and modest, but soon increasing luxury added palace to palace with such expedition and sumptuosity, that ground was wanting for the vast demand; enterprising architects, supported by infinite wealth, carried their foundations into the sea, and drove that element back from its ancient

limits*: it has since taken ample revenge, and recovered much more than it ever lost.

From being a place of resort for a season, Baiæ now grew up to a permanent city; whoever found himself disqualified by age, or infirmity, for sustaining any longer an active part on the political theatre; whoever, from an indolent disposition, sought a place where the pleasures of a town were combined with the sweets of a rural life; whoever wished to withdraw from the dangerous neighbourhood of a court, and the baneful eye of informers; flocked hither, to enjoy life untainted with fear and trouble. Such affluence of wealthy inhabitants rendered Baiæ as much a miracle of art as it was before of nature; its splendour may be inferred from its innumerable ruins, heaps of marbles, mosaics, stucco, and other precious fragments of taste.

It flourished in full glory down to the days of Theodoric the Goth; but the destruction of these enchanted palaces followed quickly upon the irruption of the northern conquerors, who overturned the Roman system, sacked and burnt all before them, and destroyed or dispersed the whole race of nobility. Loss of fortune left the Romans neither the means, nor indeed the thought, of supporting such expensive establishments, which can only be enjoyed in perfection during peace and prosperity. No sooner had opulence withdrawn her hand, than the unbridled sea rushed back upon its old domain; moles and buttresses were torn asunder and washed away; whole promontories, with the proud towers that once crowned their brows, were undermined and tumbled headlong into the deep, where, many feet below the surface, pavements of streets, foundations of houses, and masses of walls, may still be descried. Internal commotions of the earth contributed also largely to this general devastation; mephitic vapours and stagnated waters have converted this favourite seat of health into the den of pestilence, at least during the estival heats; yet Baiæ in its ruined state, and stripped of all its ornaments, still presents many beautiful and striking subjects for the pencil.

As we rowed under the lofty headlands, a Cicerone, whom I had met with at Baiæ, pointed to vaults and terraces, and allotted them

* Marisque Baiis obstrepentis urges
Summovere littora.—Hor.

respectively to the residence of some illustrious personage of antiquity. The sands abound with fragments rolled from the ruins, and some men employ themselves in the summer time in dragging the bottom of the sea with small baskets: they wash the sand in several waters, and seldom fail of bringing up a cornelian or medal that repays them for their time and labour.

From the highest point that forms the bay, a large castle commands the road, where foreign ships of war usually ride at anchor, the harbour of Naples not being spacious enough for the reception of a fleet: here they enjoy good shelter, watering, and victualling; but in summer risk the health of their crews, on account of the unwholesomeness of the air.

At the bottom of the bay, and at the foot of the steep rocks which serve as a foundation to the ruins called Nero's house, are some dark caves of great depth, leading to the hottest of all vapour baths: nobody can remain long in them, or indeed penetrate to the end, without an extraordinary degree of strength and resolution *. The springs at the bottom of the grotto are so hot as to boil an egg hard almost instantaneously. These caverns seem to be the spot where Nature has opened the readiest access to the very focus of a volcano, which has been within the two last centuries most outrageous in its operations; for to them must be attributed the overturning of the adjacent country, and the total alteration of its surface, by the birth of Monte Nuovo, which now blocks up the valley of Averno. In 1538, after previous notice by repeated quakings, the convulsed earth burst asunder, and made way for a deluge of hot ashes and flames, which being shot up to an immense height into the darkened atmosphere, fell down again all around, and formed a circular

* These baths, thirty in number, are said, but how truly I know not, to have been adorned with Greek inscriptions, and statues denoting by their expressions and attitudes, what particular part of the human frame was affected and relieved from its pains by each particular bath. Parrino, in his Theatre of Viceroys, informs us, that three physicians of Salerno, apprehensive of the ruin the surprising efficacy and reputation of these waters would bring upon their college, came hither in the dead of night, mutilated the figures, defaced the letters, and, as far as their time would allow, disturbed the course of the springs; but the historian adds very gravely, that Hygeia, ever watchful over the health of Naples, revenged this bararous outrage, by conjuring up a storm that buried the three doctors in the sea, before they could reach their home, or triumph in the success of their villainy.

mound four miles in circumference, and one thousand feet high, with a large cup in the middle. Immediately after the explosion, the wind rose furiously, and wafted the lighter particles over the country, burning and blasting all vegetation in its progress: wherever these ashes, impregnated with poison, adhered to the grass, death became the immediate lot of all beasts that brouzed upon it. The terrors occasioned by this phenomenon threatened the abandonment of the whole district; scarcely a family durst remain even within sight of this horrid heap, which had overwhelmed a large town, filled up a lake, and buried under it a very extensive tract of cultivated lands. To encourage people to return to this neighbourhood, Don Pedro de Toledo, viceroy of Naples, built a villa, and fixed his residence at Puzzuoli; his example, and time, that soother of woe, overcame the general consternation. When men are obliged to apply to daily labour for sustenance, and their minds are of course exclusively occupied by the idea of present necessities, the images of past disasters are easily obliterated, and, therefore, in a few years Don Pedro saw this district repeopled.

Part of Monte Nuovo is cultivated; but the larger portion of its declivity is wildly overgrown with prickly broom, and rank weeds that emit a very fœtid sulphureous smell. The crater is shallow, its inside clad with shrubs, and the little area at the bottom planted with fig and mulberry trees; a most striking specimen of the amazing vicissitudes that take place in this extraordinary country. I saw no traces of lava or melted matter, and few stones within.

Near the foot of this mountain the subterraneous fires act with such immediate power, that even the sand at the bottom of the sea is heated to an intolerable degree.

A long neck of land prevents the waves from washing into a sedgy pool, the poor remnant of the Lucrine lake, once so renowned for the abundance and flavour of its shell-fish, of which large beds lined the shallows, while a deep channel in the middle afforded riding and anchorage for vessels, and a passage into the inner bason of Avernus; a small canal now serves to discharge the superabundant waters. I suppose, that originally the Lucrine was only a marsh overflowed by the sea, till Hercules gave it extent and depth, by rising a mound across, and damming out the salt water; that afterwards Augustus formed the Julian port, by raising this wear to a sufficient level, and thereby procuring depth of water for a navy to float in.

[*Swinburne's Travels.*]

5. *The Lake Avernus.*

A SHADY walk conducted me, between Monte Nuovo and a thicket of reeds, to the banks of Avernus. This lake is circular, and hemmed in by an amphitheatre of hills on every side, except the break by which I approach it; distinctive marks of a volcanic crater.

The landscape, though confined, is extremely pleasing; the dark-blue surface of these unruffled waters, said to be three hundred and sixty feet deep, strongly reflects the tapering groves that cover its sloping inclosure: shoals of wild fowl swim about, and kingsfishers shootalong under the banks; a large octagon temple in ruins advances majestically to the brink; its marble ornaments have long been removed, but its form and size still render it a noble object. It was, probably, dedicated to the infernal gods, to whose worship these solemn scenes were formerly consecrated. Black aged groves stretched their boughs over the watery abyss, and with impenetrable foliage excluded almost every ray of wholesome light; mephitic vapours from the hot bowels of the earth, being denied free passage to the upper atmosphere, floated along the surface in poisonous mists. These circumstances produced horrors fit for such gloomy deities; a colony of Cimmerians, as well suited to the rites as the place itself, cut dwellings in the bosom of the surrounding hills, and officiated as priests of Tartarus. Superstition, always delighting in dark ideas, early and eagerly seized upon this spot, and hither she led her trembling votaries to celebrate her dismal orgies; here she evoked the manes of departed heroes—here she offered sacrifices to the gods of hell, and attempted to dive into the secrets of futurity. Poets enlarged upon the popular theme, and painted its awful scenery with the strongest colours of their art. Homer brings Ulysses to Avernus, as to the mouth of the infernal abodes; and in imitation of the Grecian bard, Virgil conducts his hero to the same ground. The holiness of these shades remained unimpeached for many ages: Hannibal marched his army to offer incense at this altar; but, I believe, he was led to this act of devotion rather by the hopes of surprizing the garrison of Puteoli, than by his piety.

After a long reign of undisturbed gloom and celebrity, a sudden glare of light was let-in upon Avernus: the horrors were dispelled, and with them vanished the sancity of the lake; the axe of Agrippa brought its forest to the ground, disturbed its sleepy waters with

ships, and gave room for all its malignant effluvia to escape. The virulence of these exhalations is described by ancient authors as very extraordinary; modern writers, who know the place in a cleared state only, charge these accounts with exaggeration; but I think them entitled to more respect, for even now the air is feverish and dangerous, as the jaundiced faces of the vine-dressers, who have succeeded the Sibyls and the Cimmerians in the possession of the temple, most ruefully testify.

Boccaccio relates, that, during his residence at the Neapolitan court, the surface of this lake was suddenly covered with dead fish, black and singed, as if killed by some *subaqueous* eruption of fire. At present it abounds with tench; the Lucrine with eels. The change of fortune in these lakes is singular: In the splendid days of imperial Rome, the Lucrine was the chosen spot for the brilliant parties of pleasure of a voluptuous court; they are described by Seneca as the highest refinement of extravagance and luxury; now, a slimy bed of rushes covers the scattered pools of this once-beautiful sheet of water, and the dusky Avernus is now clear and serene, offering a most alluring surface and charming scene for similar amusements.

Opposite the temple I entered a cave usually styled the Sibyl's Grotto; it seems more likely to have been the mouth of a communication between Cuma and Avernus, than the abode of a prophetess; especially as the Sibyl is positively said by historians to have dwelt in a cavern under the Cumean citadel. A most acute and indefatigable unraveller of antiquarian clews thinks it was part of the canal that Nero childishly projected from the mouth of the Tiber to the Julian port; a scheme that was crushed in its infancy.

On every hill, in every vale of the environs, appear the ruins of extensive villas, once embellished with all the elegancies of combined art, now traced only by half-buried mouldering walls, and some marble fragments, left as it were to vouch for the taste and costliness with which they were constructed. In the last period of the commonwealth, and during the gaudy æra of the Cæsars, almost every person of exalted rank had a house in this country, which the sagacious antiquaries of Puzzuoli point out to you, without doubt or hesitation. One ruin among the rest has a superior claim to our attention, and, in a great measure, pleads our excuse for yielding such easy belief to the suspicious authority that stamps it with a name: here, we are told, Cicero had his Academy, where he penned

some of his most admirable productions: it is at least a pleasing illusion to fancy that we are treading ground on which that great man took his solitary walks, and mused on the falling fortunes of Rome, or the most sublime points of morals and metaphysics *.

After many hours spent in a manner most satisfactory to my curiosity, I closed the agreeable tour of the day with a moonlight walk to Puzzuoli. The air was mildly agitated by the wind from the land, which after sunset always succeeds the sea-breeze; the waves dashed gently against the ruined edifices that impede their progress †; the reflection of the moon, and some vessels under sail, enlivened the marine prospect, and from the gardens of the vale were wafted the most delicious perfumes.

6. *The Lake Fucinus, now named Celano.*

As soon as the weather would permit, we visited the lake of Celano, so called by the moderns from a town near its north shore, the head of the earldom that comprehended at one time the greatest part of the country of the Marsi. This was the ancient name of the people that inhabited the environs of the lake, allowed by the Romans to be the most intrepid soldiers of their legions, when in friendship, and the most formidable of their enemies when at variance. It was a common saying, that Rome could neither triumph over the Marsi, nor without them. In the 662d year of Rome, they put themselves at the head of the social war, one of the most obstinate and dangerous oppositions ever made to the progress of the Roman power: it was terminated by a grant of those privileges for which they contended. Their name still subsists in that of the diocese, for the prelate is styled bishop of the Marsi.

In ancient times, the lake was called Fucinus, and was under the

* From Pliny's topography it is probable that it stood on a spot covered by the eruption of 1538.

† These buildings, which for so many ages have withstood the daily assaults of a boisterous element, owe their durability to the cement with which their parts are united; the principal ingredient is a fine volcanical sand, called Puzzolana; that acquires strength and hardness by lying under water; it consists of various metallic, stony, and earthy particles, calcined and triturated in the central furnaces, and is found both in the neighbourhood of Puzzuoli and in that of Rome.

protection of a god of the same denomination, whose temple stood on its banks. According to the testimony of ancient authors, it was subject to extraordinary risings and decreasings. The actual circumference is forty-seven miles; the breadth in the largest part, ten, in the narrowest, four; its depth, twelve feet upon an average. But all these have varied prodigiously. Two miles up the plain, behind Avezzano, the fragments of boats, shells, and other marks of its ancient extent, have been casually discovered; and, on the contrary, there are people who remember when it did not flow nearer than within two miles of Avezzano. An immense tract of excellent land is lost at every increase of its level, and if any means could be devised for draining it, or at least reducing its size, the value of the ground recovered for cultivation would be more than an equivalent for any expense incurred in the works.

All round this noble piece of water rises a circle of grand mountains, some of them the highest in Italy, if we except the Alps. The Rocca di Cambio is accounted the most elevated among them; in summer this country must be a delightful place of abode, for the environs of the lake are well inclosed, and the sides of the hills covered with fine woods; its waters abound with fish of various kinds, and thither repair, at stated seasons, innumerable flights of wild fowl. The necessaries of life are good, plentiful, and cheap: scarcely a town but is celebrated for the excellence of some particular species of food.

We rode along the edge of the lake, which was excessively agitated by the high wind, and resembled a dark stormy sea; at the distance of a mile and a half from the town we came to the mouth of the emissary or opening made by the order of Claudius Cæsar for the discharge of the waters into the Liris *, which runs

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* Dio says, the emperor intended to convey the waters into the Tiber; which could only be by means of the Salto, the Velino, and the Nera, through all which they must have passed before they fell into the Tiber, unless he meant to carry them upon arches over the Liris, and through a double chain of hills to the source of the Teverone. The Salto is too far off, and, I imagine, upon much too high a level.

Cluverius asserts, that nobody now knows where the emissary was; and that the works shewn for it are no more than the vestiges of a small canal, where the river Pitonius entered the bowels of the mountains, out of which it did not emerge till it reached the valley of Subiaco, where the aqueducts began that conveyed it to Rome, by the name of the Aqua Martia. Pliny tells a

in a deep valley on the other side of the hills. The opening is now choaked up, and lies at the foot of the hill, much below the present level of the water; in a line from it up the slope are six perpendicular wells, and two oblique grooves to the canal, which was driven through the hill into the opposite valley, and there had a vent at Capistrelli, two miles from the lake. The water is said to flow as far as the centre of the hill, and to be there twenty feet deep, but being obstructed by earth fallen in, or want of level, proceeds no further. Oblique collateral galleries were also contrived for the purpose of clearing the channel of rubbish, as the workmen advanced. As the swelling of the lake was attended with incredible damage, the Marsi had often petitioned the senate to drain it; Julius Cæsar would have attempted it, had he lived longer. His successors were averse to the project, till Claudius, who delighted in expensive, difficult enterprizes, undertook it. During the space of eleven years he employed thirty thousand men in digging a passage through the mountain, and when every thing was ready for letting off the water, exhibited a superb naval spectacle on the lake.

A great number of condemned criminals were obliged to act the parts of Rhodians and Sicilians in separate fleets, to engage in earnest, and to destroy one another for the entertainment of the court, and the multitude of spectators that covered the hills; a line of well-armed vessels and rafts loaded with soldiers surrounded the scene of action, in order to prevent any of the wretches from escaping; but it was with great difficulty and many threats that they could be brought to an engagement. When this savage diversion

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wonderful story of this river's rising in the distant mountains of the Peligni, and traversing the Fucine lake, without mixing its waters with it. Those of the lake are themselves limpid and wholesome, and if they were to be conveyed to Rome in pipes, would certainly be as pure and good as any spring-water whatever. As the long term of eleven years, with an enormous multitude of hands, was employed in this excavation, it may perhaps have been carried as far as the beginning of the aqueducts in the vale of the Teverone, where the ruins are still to be seen, though at least twelve miles in a straight line from the lake. Frontinus mentions his having discovered the real source of the Aqua Martia, between Carseoli and Subiaco, thirty-six miles from Rome; near Rio Freddo in the Roman state are several wells, or air-holes, that were contrived for the use of the subterraneous conduit, by which its waters were there conveyed through a mountain.

was ended, the operations for opening the emissary commenced and the emperor was very near being swept away and drowned by the sudden rushing of the waters towards this vent. However either through the ignorance or negligence of the engineers, the work did not answer as was expected, and Claudius did not live long enough to have the faults amended: Nero abandoned the scheme through envy. Hadrian is said to have let off the waters of the Fucinus, but none now escape except through hidden channels formed by nature, which are probably subject to be obstructed, and thus occasion a superabundance of water in the lake, till some unknown cause removes the obstructions, and again gives free passage. As three considerable streams fall into the lake, the least obstacle to a discharge must raise the level.

7. *Rivers Anio and Liganthin; the celebrated Cascade of the former, and the surrounding Scenery.*

THE general features of this interesting and classical tract of country, are so elegantly delineated in the following letter, written on the spot, that we shall make no apology for inserting it, though in a few places it may be thought, perhaps, slightly to digress from the immediate subject before us.

Rome, May 15, 1795.

I have been detained (as you will perceive by the date of this letter) much longer than I expected on my excursion to the Villa of Horace. This was chiefly owing to the weather, which was by no means *Italian*—But the number of pleasing scenes, and interesting objects, that occur at every step of this little tour, to one who is fond of either classical antiquities, natural history, or landscape, infinitely overpaid me for this trifling mortification.

The road lies through Tivoli, which is at the distance of about eighteen miles from Rome: a place of which Horace speaks so often and so affectionately under the name of Tibur.

> May Tybur, founded by the Argive Chief,
> Be my retreat in age; there may I rest
> At last, o'erspent with travel and with war.

But in order to take matters regularly, I must first stop you short of Tivoli about two or three miles, where the road is crossed by a sulphureous stream, in smell and taste very much resembling that of Harrowgate. It flows with great rapidity between two steep banks, that have not long since been made to carry it off. Here my poor dog Turque (with whose face you are acquainted by Mr. Tischbein's etching of it) had nearly fallen a sacrifice to my curiosity, or as you may perhaps call it my levity. Being desirous to see how he would like bathing in a stream of such *mauvaise odeur*, I threw a stone in, that he might dive for it. But he had no sooner plunged, than the violence of the torrent carried him above a hundred yards down, before we could overtake him, so as to give him any assistance; and even then, the banks were so exceedingly steep, that it was not without difficuly we succeeded in our efforts to get him out.

Upon tracing this stream about a mile upwards, we found its source in the little lake, from thence called Lago di Solfatara di Tivoli, which is further remarkable for the phenomena of certain little floating islands, some of which were fortunately driving about in the wind at the time we arrived, and others at anchor in the bays and harbours of this small lake. Our guide informed us they would bear *Christians*, who very frequently get upon them and push themselves about with a long pole for the amusement of strangers.

There are remains of some ancient baths, which are known to have been frequented by Augustus; and Galen mentions them as being good for rheumatisms and cutaneous disorders, but at present they are totally abandoned.

It is extraordinary that these springs not only supply water for bathing, but literally the *materials* also for building *baths*.

It appears that they formerly overflowed (as indeed they would do at present, if not carried off by the channel abovementioned) a large tract of land, and by their successive depositions of the calcareous particles that abound in them, have, in a series of ages, formed immense quarries of an excellent stone for building, which is called Travertino.

This was in great use among the Romans, as appears from many of the ruins which remain to this day, and particularly from the Colosseum, or great Amphitheatre of Vespasian, of which I gave you an account in a former letter. I visited a quarry now working

to supply materials for the new palace building by the pope's nephew, the Duke Braschi, and was much pleased with the ocular demonstration of the gradual formation of the stone in the manner already mentioned.

Near the place where this stream crosses the road, there is a great quantity of a wild flowering shrub (of which I have forgotten the name) but in Judea it attains to the height of a tree; and it is said to have been upon one of this species that Judas hanged himself.

About a mile on the other side of the road, lie the ruins of the enormous villa of Adrian; which is said to have been seven miles in circumference. The grand scale of the fragments that still remain, and their distance from each other, make this account extremely probable.

The soldier's quarter is one of the most entire, and might still serve as barracks for a vast number of men. There are remains of two theatres in a great degree perfect, besides another adapted for the representation of naval combats; the water for which was amply supplied by aqueducts from the neighbouring mountains. There are also traces of a most spacious Hippodrome, and very extensive baths; in one or two of which, the very elegant stucco is still perfect.

The number of statutes that have been dug up here is almost incredible. There is hardly a grand collection in Rome, which has not obtained from it some of its principal ornaments. It seems as if Adrain had collected here the choicest works of art, in every kind, and of every country; or at least caused imitations to be made of them, when he could not get the originals.

This is clearly the case with respect to Egyptian antiquities; as there is in the museum of the capitol a whole room allotted to statues, made in imitation of the Egyptian, that were dug up in the villa of Adrian.

This soil is still fruitful of statues, to those who will be at the pains and expence of digging for them; and it is not long since that Mr. Hamilton, an English artist, who has long been settled here, found a statue of Antinous, which was valued at two thousand pounds, but sold I believe for something less to his holiness, who intends it as a present to his nephew. The situation of the villa is upon a gentle eminence that commands a distant view of Rome, and

a very grand, and pleasing one of the mountains on each side of Tivoli.

The ground is agreeably varied, and the soil seems very favourable for trees. The air, though surrounded by the compagna di Roma, is said to be perfectly healthy.

Returning into the high road from Rome to Tivoli, where it crosses the river by the Ponte Lucana, we find the ancient tomb of the Plautian family; which is a large round tour built of great blocks of Travertino. The cornice that runs round the top, is ornamented with bulls' heads, interlaced with festoons of flowers. There are also some remains of columns, &c. in which respect only, (with the exception of being something smaller,) it differs from the tomb of Cecilia Metella near Rome.

There is reason to suppose that the battlements were added by the Goths, who converted it into a fortress.

Soon after, we began to mount the side of what Horace calls the 'supine Tibur,' through a beautiful wood of olives, in which we found a quarry of flowering alabaster.

We were here diverted with a lad, who, according to the custom of the country, was driving a horse, rather heavily laden, with stones instead of a whip. This enabled him to keep at a very respectful distance from the tail of a horse, who, if ever he halted, or turned out of the way, was sure of a stone's falling upon his rump so exactly in the same place, that his conductor must have practised long to acquire so much dexterity.

The town of Tivoli is wretched, dirty, and uninteresting in itself, but the situation, of it is so enchanting that I am almost inclined to join Horace in the preference which he gave it to all the places he had seen.

After the lapse of so many ages, the characteristic beauties of Tivoli continue so exactly the same, that it is impossible to give you in *few* words a general idea of them, better than by a literal translation of the poet's *own* words, Ode 6. B. I.—"The patient Lacedæmon, and the fields of rich Larissa, delight me less than the house of the resounding Albunea, the headlong Anio, the grove of Tibur, and orchards moist with streams, that change their course at pleasure."

The house of the resounding Albunea is the chief ornament of Tivoli, and one of the most beautiful remains of antiquity.

It is a small round temple, of which the inner part is inclosed by a high wall, that (in conjunction with the external colonade) supports the roof of the temple. The columns are of an order resembling the Corinthian, and of exquisite beauty and workmanship: and the whole is so happily proportioned, as to give it an air of grandeur, which certainly does not result from its size. It is seated on the edge of a steep rock, full in the spray of the 'headlong Anio.' This is the grand cascade, at the foot of which, the water, in a succession of ages, has hollowed grottoes of various shapes and sizes, that baffle every description but that of the pencil, to which they are most happily adapted,

The grotto of Neptune is the most celebrated; and is indeed uncommonly picturesque. Upon, or rather in the rock which fronts the opening of this grotto, are some remains, imagined by many people to be those of the house of Manlius Vopiscus, which Statius has described in a poem of more than a hundred lines. I have little doubt however that they are mistaken, from the description itself, which speaks of more buildings than it would have been possible to place in a mere chasm, or (to use a word common in the north of England) *gill*, between lofty and perpendicular rocks. Besides, if here, it would have been full in the noise and even spray of the grand cascade; which Statius speaks of it as a place 'where Anio, though rocky both above and below it, lays aside his swelling rage and foaming murmurs, from a fear of disturbing the inspired slumbers of Vopiscus, who was himself a poet.'

But whether situated here, or as I fully believe, where the ruins called Ponte Lupo are still visible, it must have been altogether an *unique*, being built in two parts or pavilions, having each a centre and wings, on the opposite sides of the river: these were most probably connected with each other by the very bridge I have mentioned, while a tree growing in the middle was preserved with so much care, that its branches were allowed to spread through the columns and even the roofs of the building.

The air of Tivoli appears to have been very friendly to poetry; as many of the poets are known to have had country houses here. That of Catullus in particular is pointed out. But it is not improbable, that the circumstance of Mæcenas having a country house here, might have a greater share in this inspiration than all the natural beauties of the place.

It is precisely through the ruins of the palace of Mæcenas, that there still flows one of the moveable rivulets, of which Horace has appeared to speak with so much pleasure. These streams are all of them diverted from the Anio (now the Teverone) and after watering the gardens, and turning the mills of the town, fall into the natural bed of the river, in the most varied and beautiful cascades; which, to distinguish them from the grand fall, are called by the Italian diminutive *Cascatelle.*

The Grove of Tibur consists principally of olives, the most picturesque trees of the kind I have seen; and from the openings between them, you catch many fine points of view; particularly one, where you see the high rock on which the town stands, silvered with its numerous cascades; and betwixt this and the olive woods that shelve down to the river, the distance is filled up with the extent of the Campagna di Roma, intersected with ths public road, and terminated by the dome of St. Peter's. Another is from a small grotto, immediately overhanging the Teverone, from which you see the largest of the cascatelle falling in two streams upon the huge moss-grown rocks below, where it meets the main body of the river, which tumbles, in broken falls, through the contracted valley in front.

In returning to Tivoli by another route, nearly parallel to the course of the river, through the lower part of 'the forest of Tiburnus,' we find some ruins, commonly called those of the house of Quintilius Varus.

There is a delightful view from hence through the wood to the scite of Catullus's villa, which was certainly *at,* though he would not allow it to be *upon,* the foot of the first Sabine mountain, on account of the contempt in which Sabine rusticity appears from the following lines, to have been holden by the *fashionables* of his day, who frequented Tibur:

> My Sabine or Tiburtine farm
> Which they who would Catullus charm,
> *Tiburtine* call; but they who hate,
> Will *Sabine* prove a any rate.
>
> Catull. in fund. v. 655.

Here too the larger cascatelle are just seen through the openings of the trees, while the three smaller ones rush murmuring through the

ruins of the villa of Mæcenas, down the woody steep which forms the opposite bank of the river, and present the painter with one of the most picturesque objects imaginable, the foreground to which varies beautifully with every step he takes.

But I must now quit Tivoli, which I believe no lover of landscape ever did without regret, and hasten to the main object of my excursion, the villa of Horace.

The villa of Horace was situated about fifteen miles from Tibur, and about four from the ancient Via Valeria. So late as the year 1767, a Frenchman of the name of Chaupy claimed the honour of having *discovered* it, though the fact is, that the greater part of the ancient geographers had placed it where he does, in the valley of Licenza. The Abbé Dominico de Sanctis, who has exposed the absurdity of Chaupy's pretensions, has written a book upon the same subject, which is certainly in one respect better than his—it is shorter; his proofs too are drawn from the best of authorities—the words of Horace himself.

He sets out with shewing, that Horace had but one villa, and that in the part of Sabina not far from Tivoli; from the circumstance that though Horace is perpetually speaking of different places of summer resort which he frequented, as Tarentum, Tivoli, Baiæ, Præneste, &c. he never mentions his having any *property* in any other place, and says expressly, B. 2. Ode 18. "I neither ask the gods for more, nor solicit my powerful friend for greater favours, being fully content with my Sabine farm alone." And again, Ode 18, Book 2,

> Why should I change my Sabine vale
> For riches more oppressive?

And to Mæcenas, Ode 1, B. 5, he says,

> Enough and more thy bounty hath enrich'd me.

But nothing, as the Abbé observes, contributes so much towards finding out the exact part o the Sabine territory in which it was situated, as to ascertain the places near to which it lay; and Horace has mentioned three; the ancient temple of Vacuna, Varia, and Mandela.

Varia, (to which as to the county town, he mentions, Epist. 14, B. I. that his village used to send five heads of families to transact provincial business) preserves apparently its name even unto this day. Vicovaro in Italian signifying the town of Varus, to which it is probable it belonged, and the more so as Varus had a country seat so near as Tivoli.

Bardella, as appears by an inscription dug up about the year 1760, stands on the scite of the antient Mandela *. This circumstance, together with the resemblance in sound between the names Digentia and Licenza, as pronounced by the natives, seems to prove that this is the river of which Horace speaks. B. 2. Sat. 6. "As often as the cool stream of Digentia refreshes me which Mandela drinks, a town wrinkled with cold," &c. Again, Horace ends his epistle to Fuscus, B. 1. E. 10, saying, "I write this to you from behind the mouldering fane of Vacuna."

Now Varro asserts that the goddess Vacuna, worshipped by the Sabines, meant Victory: and it appears by an inscription found about thirty years ago, in digging about the ruins, commonly supposed by geographers to have been those of the temple of Vacuna, that the temple of Victory on that spot was rebuilt by the Emperor Vespasian, about a hundred years after the time of Horace, who speaks of it as in ruins †.

Add to this that it is within an easy walk of the spot upon the borders of the Licenza, so marked out as the farm of Horace.

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* The inscription (which is on marble, and was found in the angle, formed by the confluence of the Licenza and Taverone) runs literally thus—Val. Maxima Mater Domni predia Valeria dulcissima Filia quæ vixit annis xxxvi Men. ii. D. xii. in prediis suis MASSE MANDELANE Sep. retorum Hercules Quesq n pace.

As it is impossible even for a classical scholar unaccustomed to the initial contractions and changes of letters frequent among the ancients, to make sense of this inscription (which Chaupy infers from its stile, the form of the letters, and the Christian phrase of *quiescant in pace*, to have been written about the end of the third or the beginning of the fourth century). I here subjoin that which he argues with much ingenuity and plausibility, was intended to be the reading at full length, viz. Valeria Maxima Dotibus omnibus prædita, Valeria dulcissima filia quæ vixit annos 36 menses 2. dies 12. in prædiis suis (quæ voc.) Massæ Mandelanæ Sepulchrum restituit et ornavit Valerius Maximus Hercules. Whatever may be thought of the sense of the inscription, the vicinity of MANDELA is fortunately established by it beyond all possible doubt.

† The inscription is Imp. Cæsar Vespasianus Aug. Pontifex Maximus Trib. Potestatis Censor Ædem Victoriæ Vetustate dilapsam sua impensa restituit.

If these antiquarian proofs were less strong, the place itself would bear no feeble testimony to its having been the seat of Horace, as there is not any one of the numerous descriptions he has left of it, to which it does not at this day perfectly answer. Of these I was better enabled to judge by reading Horace upon the spot, and it will, probably, as you are so fond of reading him at home, be the pleasantest method I can take of describing the modern appearance of the placè, to refer you to his own descriptions of it in its ancient state.

In the 16th Epist. Book 1. he says to his friend Guinctius, "Lest you should ask whether my farm feeds its owner by tillage, or enriches him with olives, with orchards and pasture, or the elm clothed with vines—I will describe to you at length the form and situation of it.

"It is surrounded by mountains uninterrupted except by a shady valley: of which the sun rising beholds the right side, and warms the left with his retreating car. What if it produces kindly cornels and wild plums, while the oak and holm oak delight the cattle with their fruit, and their master with their shade. You would say that Tarentum itself was brought hither with all its groves. There is a spring fit to give name to a river, cooler and purer than which Hebrus not encircles Thrace. It flows useful in pains of the head and indigestions. These retreats, pleasant, and even (if you will believe me) delightful, keep me in health during the unwholesome hours of September."

Upon this *text* I make no further comment than to observe, that all the trees here mentioned are found so plentifully as to appear the spontaneous growth of the country, though the difference of culture probably has introduced such a number of olives, walnuts, and chesnuts, that they would hardly have escaped the mention of so accurate a painter of nature as Horace, if they had existed so plentifully in his time.

In every other respect the situation answers as perfectly as if the description had been just written; and the circumstance of the vines being raised on elms, continues to this day, though at so small a distance as Tivoli, the custom is universally to prop them upon reeds, of which they make large plantations for that purpose.

'The spring is not only "fit to give name to the stream that waters the valley of Licenza, but is sometimes so abundant as to oc-

casion an overflow of the low ground which it encircles, conformably to what Horace says in reckoning the occupations of his bailiff, Ep. 14. B. 1. "The river, after a fall of rain, affords an additional employment for your idleness, to be taught at the expense of many a mound to spare the sunny meadow."

The bailiff's complaint that "that corner of the land would bear pepper and frankincense sooner than the grape," is thus far just, that the grapes do not succeed so kindly as the hardier fruit trees, and still produce that rough kind of wine which Horace so frequently describes.

> THIS WAS MY WISH; a farm not over large,
> A garden, and amid the neighbouring hills
> A fountain, and o'er these a little wood—
> The Gods have more and better given me—
> 'Tis well—" Book 2nd. Sat. 6.

In an orchard, through which trickles the water from the neighbouring spring crowned with the incumbent woods of Lucretilis, is found a considerable fragment of mosaic pavement, which may, with the highest degree of probability, be deemed a relic of the house of Horace.

The ground is well strewed with fragments of various marbles, such as might be supposed to ornament the retreat of the elegant favourite of Mæcenas; at the same time that no massy or magnificent ruins remain to give the lie to his professions of philosophic moderation. I have picked up some specimens which I hope to bring you home, and a bit of glass, which appears much of the same sort with that found amongst the ruins of Herculaneum.

Adjoining the vineyard is a beautiful little chesnut grove, at the foot of which winds the river I must now beg leave to call the Digentia.

In this delightful spot, which through different openings of the trees presents almost every object worthy of note in the descriptions of Horace, relative to this place—*you* will readily believe I passed a few hours very agreeably, without any other company than that of Horace.

I had taken up my lodging at the house of the arch-priest, who is a Portuguese ex-jesuit, a very civil man and not ill-formed. I had the pleasure of finding in his library (which by the bye was the

only spare bed-room he had to offer me, and between the books and the bed you might *set* a chair, but not *turn* it) a set of Chaupy's essays upon the antiquities of the place, which upon the spot were interesting and particularly satisfactory, as they tended to confirm all the reasons above stated, concerning the identity of the spot.

During my stay with the arch-priest, I made several pilgrimages to the most interesting spots in the neighbourhood, particularly to the ruins of the *restored* Temple of Vacuna, which are now only known to be such by the inscription before mentioned to have been dug up there.

As Horace says nothing more of the temple than that it was in a ruinous state, and that he wrote behind it. I had little more to interest my imagination than to form to myself the landscape, such as it probably presented itself to him at the time of writing, and hope in some degree to communicate my idea of it to you by the help of a rough sketch which I made upon thespot.

Upon this excursion I was unexpectedly attended by two lads of the village, whose curiosity appeared to be so strongly excited concerning me, that I could not find in my heart to send them away; particularly as from their sprightly naiveté I could scarcely help fancying them to be the lineal descendants of the *vernæ procaces* (frolic hinds) whose sallies appear to have afforded pleasure even to the mind of Horace. Upon our return we were overtaken by a smart shower, which obliged us to take shelter in a hermitage near the chapel of Madonna delle Case. The hermit was (as usual) an ecclesiastic; and upon my putting some questions to him respecting the salubrity of the situation, answered, we take "reverendissima cura della salute?") (a most reverend care of our health:) This reminded me so forcibly of Falstaff's advice to the Lord Chief Justice, that I could not refrain from a smile, which I fear he thought heretically sarcastic, as he immediately added, (crossing himself very devoutly) "cioè primò della salute dell'anima, è poi di quella del corpo," that is, "first of the soul's health, and afterwards that of the body."

My visit to Fonte-bello, the source of the Digentia, that tumbles down a rocky gill of the mountain Lucretilis, pleased me exceedingly. I seemed to have found the original of the picture Horace has given us in the 13th Ode of Book 3, to the Fountain of Blandusiæ.

A regard for the truth obliges me to confess, that it has been

very plausibly contended by Chaupy that the Fons Blandusiæ was not at the Sabine Farm, but in the neighbourhood of the birth-place of Horace. This is, however, not only contrary to the opinions of (I believe) *all* his commentators, but (in some degree) to the evidence of Horace himself. For he tells us that he did not commence poet till his paternal estate had been confiscated; it is surely therefore *less likely* that he should write an *ode* and promise a *sacrifice,* to a fountain in an estate that he had *lost,* than in one he had since *acquired,* and to whose situation he was so partial.

Notwithstanding what I have seen of Chaupy's works, I had rather err with other geographers than think right with him: and thus far I acknowledge prejudice: but on the whole, the reasons I have given induce me to think that in *following* I do not *err* with the multitude.

The whole of the Lucretilis is so pleasant, that Faunus (vid. Ode 17. B, I.) could have no great loss in changing Lycæus for it, being now covered, as thickly as it was in the time of Horace, with goats that wander in its groves, to crop the arbutus which abounds there, with the same impunity.

The epithet of "the leaning Ustica" most happily distinguishes this situation from Tivoli, which he calls "supine," and the expression of "valle reducta," has a propriety when applied to this place, which the "withdrawing vale" seems not fully to express in English.

Ode 22. Book I. Horace mentions the circumstance of his having met a wolf upon the mountain, when he had accidentally strolled beyond his boundary—and those animals are not yet thoroughly extirpated from the vast woods that cover the heights of the mountain.

[*Bradstreet's Sabine Farm.*]

7. *The River Po, or Eridanus.*

THE Po, Padus, or Eridanus, for under all these names it has been celebrated in history and poetry of the greatest excellence, is the largest and most extensive river of Italy. In the infant state of the Roman republic, its banks were inhabited towards the head of the river by the Salassi, and lower down by the Insubres; both powerful people, who had frequent, and at times, successful contests

with the Romans; and, but their jealousy of each other, might for ever have defied the Roman arms. One of the branches of the Po was the Draria, which, at this period poured down, or was supposed to pour down gold-dust in its sands; which the Salassi endeavoured to secure to themselves before it reached the country of Insubria. The Insubres, incapable of supporting their own imagined right, appealed to the consul Appius Claudius Pulcher, who readily took advantage of the appeal, and immediately invaded the Salassi. At first, however, he was unsuccessful, being defeated with a loss of five thousand men: though upon a second battle he triumphed to an equal extent, and at length gratified himself and his countrymen by equally reducing both nations to a state of subjection.

This noble river, rises from mount Vesula, or Viso, on the very confines of France and Italy, nearly in the parallel of mount Dauphin, in Dauphiné, and Saluzzo, in Piedmont, being almost central between them, at the distance of about 18 English miles from each. Thus descending from the centre of the western Alps, the Po passes to the N. E. of Saluzzo, by Carignan, to Turin; receiving even in this short space many rivers, as the Varrita, Maira, and Grana from the south; and from the N. the Felice, Sagon and others. Most of these streams having had a longer course than what is called that of the Po, the Maira, for instance, might perhaps be more justly regarded as the principal river: nay the Tanaro, which flows into the Po, some miles below Alexandria, might perhaps claim, in the river Stura, a more remote source than the Po itself. After leaving the walls of Turin, the Po receives innumerable rivers and rivulets from the Alps in the N. and the Appennines in the S. Among the former may be named the Doria, the Tesino, the Adda, the Oglio, the Mincio: to the east of which the Adige, an independent stream, descends from the Alps of Tyrol, and refusing to blend his waters with the Po pursues his course to the gulph of Venice. From the south the Po first receives the copious Alpine river Tanaro, itself swelled by the Belba, Bormida, and other streams: the other southern rivers are of far less consequence, but among them may be named the Trebbia, the river of Parma and Panaro, which joins the Po at Stellato, on the western frontier of the former territory of Ferrara. The course of the Po may be comparatively estimated at about 300 British miles; so that when Busching pronounces it the second river in Europe, after the

Danube, he must have forgotten the Rhine, the Elbe, the Oder, the Vistula, not to mention the Loire of France, the Tajo of Spain, and other noble streams! The numerous tributary rivers, from the Alps and Apennines, bring down so much sand and gravel that the bed of the Po has in modern times been considerably raised, so that in many places banks of thirty feet in height are necessary to preserve the country from inundation. Hence hydraulics have been much studied in the north of Italy; and the numerous canals of irrigation delight and instruct the traveller. Perhaps by deepening the chief estuary, and bed of the river, equal service might have been rendered to commerce. In the middle ages maritime combats took place on the Po, between Venice and some of the inland powers. It is remarkable that, from Cremona to the sea, there is no capital city founded on the main stream of the Po; and the case was the same in ancient times; an exception to the supposition that every river has some grand city near its estuary *.

9. *The Tiber.*

This stream immortalized in both prose and verse, and by far the most considerable in the middle or south of Italy, is said to derive its name from Tiberinus, an early Latin king, and direct descendant of Oneus, by Lairnia, who was drowned in its waters in the course of a battle which was fought on its banks.

It rises near the source of the Arno, south east of St. Marino, and passes by Perugia and Rome, to the Mediterranean, which it joins after a course of about 150 miles. It is said to receive not fewer than forty-two rivers or torrents, many of them celebrated in Roman history; as is the Rubicon, a diminutive stream, now the Fiermesino, which enters the Adriatic, about eight British miles to the north of Rimini.

In consequence of these numerous torrents it occasionally overflows its banks; and in an early period of the Roman empire, before its embankment was made sufficiently powerful and lofty, these

* To the N. of Ferrara the Po seems as broad as the Rhine at Dusseldorf, Stolberg, ii. 576: but is probably not above half as deep. Dr. Smith, ii. 360, compares the Po, near Ferrara, to the Maese at Rotterdam, and says it is nearly as wide. That *Maese* is only a *branch* of the Rhine.

eruptions were not only frequent but for the most part very destructive. Thus in the reign of Trajan, we are told, that it overflowed its banks with prodigious violence, laid great part of the city under water, overturned many houses, and produced so much damage to the adjoining fields as to occasion a severe local famine; and all this, notwithstanding that the emperor had endeavoured to guard against the evil, by canals for carrying off the surplus water in the case of an inundation of the Tiber. Aurelian pursued another plan, and deepened its channel, while he enriched its banks with numerous and extensive wharfs. Still, however, it occasionally produced the same public mischief, and in the reign of Valentinian, overflowed to such a degree that it laid all the lower parts of Rome under water, and the inhabitants were obliged to save themselves upon the hills: where the greater number of them would have perished of hunger had not Claudius, prefect of the city, sent them a seasonable supply of provisions in boats. It was Valentinian who crowned the Tiber with the celebrated bridge, which was at first called the bridge of Gratian, and afterwards of Cestus. It is the Ponto di S. Bartolomeo, or St. Bartholomew's bridge, of the present day.

SECTION IV.

PERIODICAL SPRINGS AND LAKES.

1. *Introductory Observations.*

AMONG the natural phænomena that the surface of the earth displays to us, there are few more curious than those of intermitting or reciprocating fountains or other beds of water; nor is it by any means an easy matter to account for so extraordinary a fact. An irregularity of flow is indeed by no means uncommon; most of the boiling springs are subject to it. But there are others that evince almost as regular and periodical influx and reflux as the tides of the ocean; while, not unfrequently, these alterations occur several times in a day or even in an hour. Perhaps the causes are various, and are sometimes subterranean and at others superficial. Generally speaking, springs and lakes of this description have been ascertained to communicate with a lower layer of the same, through pores or apertures of various diameter, which serve equally to carry off the

THE CASTLE OF ST. ANGELO, ST. PETER'S CHURCH, & THE BRIDGE OVER THE TIBER, AT ROME.

waters and to supply them afresh. And in such cases the flux and reflux of the upper head of water must necessarily depend upon the state of that below; and the causes which alternately augment and diminish the latter must produce a similar effect upon the former. And it is possible that these causes may be, as we shall presently find was long ago ingeniously conjectured by the younger Pliny, regular currents of air produced by the penetrating influence of the sun,—a communication with the sea itself: or a periodical return of subterranean heat or other agency below the interior reservoir that may drive additional waters into it, or expand those of which it consists.

In the present day, however, the common principle upon which this phænomenon is accounted for is that of the hydraulic machine, called the Cup of Tantalus:—an instrument consisting of a vessel furnished with a siphon or tube with two legs, the one shorter than the other, and which may be attached to it in different ways. But this will not account for fountains with irregular ebbs and flows; and hence, Mr. Gough, while he attributes the regularly recurrent springs to the explanation of a siphon, has proposed another theory to account for those of a different kind, and which, in truth, is not far removed from one of the modes conjectured by the younger Pliny. Mr. Gough's theory, together with his explanation of the common theory of the siphon, we shall give in a subsequent part of the present section, allotted to an account of the alternating well at Giggleswick, in Yorkshire.

In Switzerland springs and lakes of this kind are peculiarly common; and Mr. Addison in his Travels endeavours to account for those which he met by a different process, but a process however which it must be obvious can only apply to a few. We saw, says he, in his description of Geneva and the lake, in several parts of the Alps that bordered upon us, vast pits of snow; as several mountains, that lie at greater distance, are wholly covered with it. I fancied the confusion of mountains and hollows, I here observed, furnished me with a more probable reason than any I have met with, for these periodical fountains in Switzerland which flow only at particular hours of the day. For as the tops of these mountains cast their shadows upon one another, they hinder the sun's shining on several parts at such times, so that there are several heaps of snow which have the sun lying upon them for two or three hours

together, and are in the shade all the day afterward. If, therefore, it happens that any particular fountain takes its rise from any of these reservoirs of snow, it will naturally begin to flow on such hours of the day as the snow begins to melt; but as soon as the sun leaves it again to freeze and harden, the fountain dries up and receives no more supplies till about the same time the next day when the heat of the sun again sets the snows a-running that fall into the same little conduits, traces and canals, and by consequence break out and discover themselves always in the same place. EDITOR.

2. *Comian Spring.*

PLINY TO LICINIUS.

I HAVE brought you, as a present, out of the country, a query which well deserves the consideration of your extensive knowledge. There is a spring which rises in a neigbouring mountain, and, running among the rocks, is received into a little banquetting-room, from whence, after the force of its current is a little restrained, it falls into the Larian lake *. The nature of this spring is extremely surprising: it ebbs and flows regularly three times a day.

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* Now the *Lago di Como*, in the duchy of Milan. *Como* or *Comum* is the city in which the younger Pliny was born; and upon the banks of the lake his elegant villa was situated.

In the Natural History of the elder Pliny, book II. chap. ciii. we are also told of a fountain in the vicinity of the same lake which ebbs and flows *every hour;* and Catani, and various other writers have conceived that both descriptions refer to one common fountain, and have consequently pretended to detect a palpable disagreement between the elder Pliny and his nephew; Catani supporting the testimony of the former from ocular observation, the fountain being, as he tells us, still in existence in his own time, and denominated Pliny's well. It is by no means certain, however, that the fountain described by each of these writers is the same, nor does its character, as given by the one, very strictly accord with that given by the other. The elder Pliny expressly denominates it " a large and broad well;" while the latter represents it as a small enclosed well; or in his own words, " a well received into a *little* banquetting-room." The point however is not of consequence.—There are various other wells of a similar kind which are noticed by the elder Pliny, and especially that of Jupiter, in Dodona, of which the reader will meet with a farther account in another section of this chapter. EDITOR.

The increase and decrease is plainly visible and very amusing to observers. You sit down by the side of the fountain, and whilst you are taking a repast, and drinking its water, which is extremely cool, you see it gradually rise and fall. If you place a ring or any thing else, at the bottom, when it is dry, the stream reaches it by degrees till it is entirely covered, and then gently retires; and if you wait you may see it thus alternately advance and recede three successive times. Shall we say that some secret current of air stops and opens the fountain-head as it approaches to or retires from it, as we see in bottles, and other vessels of that nature, when there is not a free and open passage, though you turn their necks downwards, yet the outward air obstructing the vent, they discharge their contents as it were by starts? But may it not be accounted for upon the same principle as the flux and reflux of the sea? Or as those rivers which discharge themselves into the sea, meeting with contrary winds and the swell of the ocean are forced back into their channels: so may there not be something that checks this fountain, for a time, in its progress? Or is there rather a certain reservoir that contains these waters in the bowels of the earth, which, while it is recruiting its discharges, the stream flows more slowly and in less quantity; but when it has collected its due measure, it runs again in its usual strength and fulness. Or, lastly, is there on I know not what kind of subterraneous counterpoise that throws up the water when the fountain is dry, and stops it when it is full? You, who are so well qualified for the enquiry, will examine the reasons of this wonderful phenomenon: it will be sufficient for me, if I have given you a clear description of it. Farewell.

[*Melmoth's Trans.*]

3. *Paderborn Spring.*

In the diocese of Paderborn, in Westphalia, there is a spring which disappears twice in twenty-four hours, returning always after six hours with a great noise, and so forcibly as to drive three mills not far from its source. The inhabitants call it the bolderborn, that is, the boisterous spring.

[*Phil. Trans.* 1665.]

There are various chemical remarks appended to the above brief

description, which, from the loose and unsettled state of the science in this early perod of its existence, are of no value in the present day. Whilst upon this diocese, however, we may be permitted to remark that Paderborn appears at the era before us to have been celebrated for various springs of an extraordinary nature, since in the same volume we meet with the following account, which we quote rather for its singularity than its containing any thing that can be very minutely depended upon in the present more accurate and cautious state of science.

"In the diocese of Paderborn, about two leagues from that town, is a spring, called Metborn, with three streams, two of which are not above one foot and half distant from each other, and yet of such different qualities, that one of them is limpid, bluish, lukewarm, and bubbling, containing sal-ammoniac, oker, iron, vitriol, alum, sulphur, nitre, and orpiment *, used against epilepsies, diseased spleens, and the worms; the other is ice-cold, turbid, and whitish, much stronger in taste, and heavier than the former, containing much orpiment, salt, iron, nitre, and some sal-ammoniac, alum, and vitriol. All birds that drink of the latter are observed to die; which I have also made experiment of, by taking some of it home, and giving it to poultry, after having eaten oats, barley, and bread-crumbs: for soon after drinking it, they became giddy, reeled and tumbled upon their backs, with convulsions, and so died with their legs much extended. Giving them common salt immediately after they had drunken, they lived longer; giving them vinegar, they died not at all, but seven or eight days after were troubled with the pip. Those that died being opened, their lungs were found quite shrivelled. Yet some persons who are troubled with worms, taking a little quantity of it diluted with common water, have been observed by this means to kill the worms in their bodies, and discharged great numbers of them: and though it makes them sick, yet not so as to endanger their lives.

The third stream, lying lower than the other two, and about 20 paces distant from them, is of a greenish colour, very clear, and of a sourish sweet taste, agreeable enough. Its weight is a medium

* The chemical analysis of mineral waters was so imperfectly understood in the 17th century, that little reliance can be placed on the number and proportion of ingredients assigned in this and other instances.

between that of the other two; whence it is probable that it is a mixture of both, meeting there together: To confirm which, we mixed equal quantities of those two with a little common well-water, and found, on stirring them together, and permitting them to settle, that they produced water of the same colour and taste as this third stream." EDITOR.

4. *Lay-well Spring.*

GOING a-shore one day, I walked about a mile into the country, to see a well much talked of, near Torbay, called Lay-well, which made me more than amends for the pains I had taken to come at it. It is about 6 feet long, 5 feet broad, and near 6 inches deep; and it ebbs and flows often every hour, very visibly; for from high-water to low-water mark, which I measured, I found it somewhat more than 5 inches. I could not see any augmentation above my mark when it flowed, nor fell it below my mark when it ebbed, but always kept the same distance. The flux and reflux, taken both together, was performed in about two minutes; nothing could be more regular, each succeeding the other as the tides of the sea do. I drank of it, and found it a pleasant, delicate, fine, soft-water, not brackish at all; which the country people use in fevers as their ordinary diet drink, which succeeds very well.

On a second visit, I observed it performed its flux and reflux in little more than a minute's time, yet it would stand at its lowest ebb sometimes two or three minutes; so that it ebbed and flowed by my watch about 16 times in an hour, and sometimes, I have been told, 20. As soon as the water in the well began to rise, I saw a great many bubbles ascend from the bottom; but when the water began to fall, the bubbling immediately ceased. The whole country adjacent is very hilly all along the coast; from Brixam to the top of the hill is about a mile and half, the well is about half way up the hill, which hereabout is somewhat uneven and interrupted, and comes out at a small descent, yet considerably higher than the surface of the sea. The water does not seem to be impregnated with any mineral, Its taste is very soft and pleasant, has no manner of roughness in it, and serves for all manner of uses to the country people in their houses *. [*Phil. Trans.* 1693.]

* There is another description of this spring contained in the same excellent Journal, year 1732, by Mr. Joseph Atwell, and attempted to be explained by him

The editors of the abridgement proceed to give a long account of Mr. Atwell's explanation of this system: but as the reader will find a much easier and simpler illustration by Mr. Gough in the ensuing sub-section, it is unnecessary to quote it in the present place. EDITOR.

5. *Giggleswick Well.*

A description of this fountain has been given by several visitors, but far better by Mr. Gough in the Memoirs of the Transactions of the Manchester Society than by any other writer we are acquainted with. This gentleman first briefly examines the nature and history of the more curious periodical springs that have been observed and described, and particularly those of Como, Dodona, and Paderborn, which he ascribes to the principle of a siphon; and then by way of explaining this principle and of developing the well in question proceeds as follows;—

This instrument consists of a vessel furnished with a siphon,

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upon the principle of siphons. "Mr. Atwell," says the writers of the recent Abridgment, "comes now to his hypothesis, for explaining the phænomena observed; and he imagines them to be occasioned by two streams or springs, one of which passing through two caverns or natural reservoirs with siphons, meets with the other stream in a third reservoir, without a siphon; where being joined, they come out of the earth together.

The petitio principii, or supposition of reservoirs and siphons in the bowels of the earth, has been made by others: Père Regnault, in his Phil. Conversations, Vol. ii. Conv. 6, p. 125, &c. Eng. edit. has mentioned it in general; and Dr. Desaguliers, in Phil. Trans. No. 384, has attempted to apply it to two cases in particular; as Dechales, Tract. xvii. de Fontibus Naturabilis, &c. prop. xv. had done in two other cases before him. It is indeed unnatural, or hard to be granted. Whoever has seen the Peak of Derbyshire, the hilly parts of Wales, or other countries, must be satisfied that they abound with caverns of many sorts. Some of them are dry, others serve only for passages, or channels, to streams, which run through them; and a third sort collect and hold water, till they are full. They must also have observed, that there are sometimes narrow passages, running between the rocks which compose the sides, and going from one cavern to another. Such a passage, of whatever shape or dimensions, how crooked and winding soever in its course, if it be but tight, and runs from the lower part of the cavern, first upwards to a less height than that of the cavern, and then downwards below the mouth of the said passage, will be a natural siphon.

which may be attached to it in different ways. To avoid the necessity of a diagram, we will suppose the bottom of the vessel to be perforated, and the longer leg of the siphon to pass through the hole, being firmly cemented in a position, which places the highest point of the bend within the vessel, and half an inch or an inch below the brim, and at the same time keeps the open or lower end of the shorter leg at a small distance from the cup's bottom. Water flows through a tube in an uniform stream into the cup; where it is collected for want of egress, and entering the siphon at the open end of the shorter leg, it rises gradually to the bend or highest point. The subsequent rise of the water in the cup, forces the column in the ascending leg of the siphon, to pass over into the descending or longer branch; upon which this instrument begins to act, not in the manner of a simple tube, but in its proper character. Now the draft of the siphon is made to exceed the opposite stream or supply of water; in consequence of which contrivance the cup is emptied again sooner or later; at this moment the action of the siphon is suspended, until the cup is replenished by the constant current. In this manner the water will be seen rising and falling alternately in the cup, which will be full and empty, or nearly so, by turns. Similar vicissitudes will also take place in the siphon; for it will run so long as its shorter leg is in the water, and then stop, until the highest point of the bend is again covered by the contents of the cup.

The transition is easily made from Tantalus's cup to a fountain, which reciprocates periodically; for we have only to suppose a secret reservoir to be formed in the bowels of a mountain on the principles of this instrument, and the following appearances will take place in the visible well, which receives the water from the natural siphon. 1st. So soon as the surface of the pool in the subterranean reservoir, rises above the bend of the siphon, this canal will begin to act; and its discharge will be greater at that moment than at any other period; because the power of a siphon is greatest, when the distance, betwixt the bend and the surface of the water in the basin, is least. 2d. This abundant influx into the external well will make it rise; in consequence of which the efflux will continue to increase at the outlet, so long as the water continues to accumulate in the visible basin. 3d. Now the discharge from the outlet, which becomes more copious every moment, being contrary to the influx

from the siphon, which grows gradually weaker, the surface of the well will cease to rise so soon as these opposite powers are equal in their effects; and the flow will be at the full in this instant. 4th. The well cannot remain stationary, for any length of time, at its highest elevation; because the vigor of the siphon being perpetually on the decline, all the water discharged by it will run off through the outlet, together with part of that, which had been previously accumulated in the visible fountain, during the time of the flow. 5th. Hence it is evident that the well will begin to subside, the moment it becomes stationary; after which it will persevere in a retrograde motion, until the siphon shall have emptied the subterranean reservoir. 6th. If no veins of water discharge themselves into the visible basin, besides the siphon which runs periodically, the spring is called an intermitting fountain. The Bolderborn is of this kind, for it remains dry while the secret reservoir is filling, and flows while the siphon is in action. 7th. But if the spring receives other supplies in addition to the intermitting current, it is called a reciprocating fountain; because the stream that issues from the outlet of the visible basin is permanent, though it varies in quantity; on this account the well ebbs and flows alternately, but never runs itself dry. All the fountains, which will be mentioned in the sequel are of this kind; and Pliny's well, near Coma, appears to possess the same character from his description of it. 8th. The fluctuations of an ebbing and flowing well, which is fed by a siphon, will remain invariable, so long as the stream, that falls into the subterranean reservoir continues to be uniform. But these external and visible operations of the well, are so far under the influence of the current last mentioned, that they will evidently suffer a temporary suspension, so often as the influx into the concealed cistern, amounts to a certain quantity in a certain time; for the siphon is but a secondary agent in producing the phenomena of reciprocation, its business being to empty the subterranean basin, so often as it is replenished. Now the time of filling this magazine of water will be the shortest, when the influx into it is most abundant, and the contrary; consequently an increased discharge into the subterranean reservoir, will diminish the intervals of the siphon's inactivity, and prolong the periods of its action. It follows, from these premises, that when the influx becomes equal to the feeblest effort of the siphon, the quantity of water thrown into the concealed basin, will exactly

counterbalance the quantity which is drawn off by the crooked canal; and the external *well* will assume the character of a common fountain under these circumstances.

I have now explained the principles, on which the common theory of reciprocating springs is founded; and the necessary consequences of the theory are stated in the eight preceding propositions. This has been done, to shew with what ease a natural apparatus on the construction of Tantalus's cup elucidates the appearances, which have been ascribed by writers to the fountains of Dodona, Coma, and Paderborn. The operations of these springs are happily illustrated by the instrument in question; on which account I do not hesitate to pronounce the theory to be a good one, so far as it relates to these fountains alone; provided they are faithfully described. The simplicity of the preceding explanation, and its coincidence with the narratives of the two Plinys, as well as the history of the inconstant brook in Westphalia, disposed me to admit the common theory, and to imagine it to be equally applicable to reciprocating fountains in general; until an instance occurred to my notice, which proved that, fluctuating fountains do not universally exhibit the periodical operations which are described by the writers already quoted. I made a visit to Giggleswick Well, in the autumn of 1796; which taught me to value this once favourite theory not so highly, and in particular to dispute the universality of its application. The causes of these doubts will be easily perceived from the following description of the well and its operations.

This spring lies at the foot of Giggleswick Scar, which is a hill of limestone in the West Riding of Yorkshire. The water discharged by it, falls immediately into a stone trough; in the front of which are two holes near the bottom; these are the outlets of two streams, that flow constantly from the artificial cistern. An oblong notch is also cut in the same side of the trough; which extends from the brim of it, nearly to the level of the two holes already mentioned. This aperture is intended to shew the fluctuations of the well: for the water subsides in it when the stream issuing from the rock becomes languid; on the contrary the surface of the water rises again in the notch, so soon as the influx into the trough begins to be more copious. The reciprocations of the spring are easily observed by this contrivance; and they appear to be very irregular both in respect of duration and magnitude. For the interval of time betwixt any

two succeeding flows, is sometimes greater, and at other times less, than a similar interval which the observer may happen to take for his standard of comparison. The rise of the water in the cistern, during the time of the well's flowing, is also equally uncertain; for it varies from one inch, to nine or ten inches, in the course of a few reciprocations. It is necessary to remark on the present occasion, that the spring discharges bubbles of air, more or less copiously into the trough; these appear in the greatest abundance at the commencement of a flow, and cease during the ebb, or at least issue from the rock very sparingly at that time. In fact, the appearance and disappearance of these bubbles, are circumstances equally inconstant with the rise and fall of the water.

The irregularities exhibited by the ebbing and flowing well, during my short visit, diminished the respect which I formerly had for the popular theory, more especially when considered as a general explanation of reciprocating springs. This change of opinion was suggested by the caprices of the well; which were too many and too singular to be ascribed to the uniform operations of a single siphon, as we have seen already; and the accidental combination of several siphons in one fountain, is a conjecture too improbable in itself to demand a serious discussion. My suspicions respecting the accuracy of the principle were not a little increased, by the following descriptions of two reciprocating fountains. Weeding Well, in Derbyshire, appears to be more fickle and uncertain in its reciprocations, than the well at Giggleswick. Dr. Plot describes this remarkable fountain, at page 41 of his History of Staffordshire, where he reports it to be very uncertain in its motions, ebbing and flowing sometimes thrice in an hour, and at other times not oftener than once in a month; he also quotes the following character of it, to the same import, from a latin poem by Mr. Hobbs.

"Fons hic temporibus nec tollitur (ut Mare) certis;
"Æstibus his nullam præfigit Ephemeris horam."

The following account of a reciprocating fountain is extracted from an article in the second volume of Lowthorp's Abridgement, page 305; in which care has been taken to preserve the facts recorded by the author, Dr. W. Oliver, in language more concise than his own. "Lay Well, near Torbay, is about six feet long,

five feet broad, and near six inches deep; it ebbs and flows very visibly; and many times in an hour. The reciprocations succeed each other more rapidly when the well is full, than they do when it is low. When once the fountain began to flow, it performed its flux and reflux in little more than a minute's time; but the Doctor observed it to stand sometimes two or three minutes at its lowest ebb; so that it ebbed and flowed about 16 times in an hour, by his watch. So soon as the water began to rise in the well, he saw a great number of bubbles ascend from the bottom; but when the water began to fall, the bubbling ceased immediately. The Doctor measured the distance betwixt the high and low water marks, not on a perpendicular line, but on a slope, and found it exceeded five inches.

The three preceding instances of irregular reciprocation undoubtedly diminishes the importance of the popular theory, by proving that it is not of universal application; as it only explains the constitution of those fountains, which ebb and flow periodically. The Bolderborn of Westphalia, may be reasonably pronounced to be of this description; as for the fountain of Jupiter in Dodona, we know too little of it to judge of its true character; and it is not improbable but future observations will add Pliny's Well to the class of irregular reciprocators.

It may be reasonably supposed, that since I have endeavoured to confine the established theory of reciprocation to one or two springs at most, a new explanation will be offered on my part, comprehending the phenomena of those wells, which ebb and flow according to no certain rule. Before I make this attempt, it will be proper to give a more circumstantial account of the appearances exhibited by the well at Giggleswick, than has hitherto been published. I neglected, when in the country, to preserve a correct register of its fluctuations, and committed no other observations to writing, except those which appear in a former part of this essay. This omission, however, has been fully supplied by Mr. John Swainston, of Kendal; to whom I formerly communicated my imperfect remarks on this well, requesting him at the same time to note down a series of its operations, at some convenient opportunity. This request was complied with by my friend; who has digested his observations in the following table, which merits the esteem of the naturalist, as being a faithful history of this singular fountain.

Observations made on Giggleswick Well, August 20*th*, 104, *from* 3 *to nearly* 6 *P. M.*

On first coming to the well it continued flowing near ten minutes, and then as in the Table.

No. of inches Ebbed.	Time in Ebbing in minutes.	Stationary at Ebb in minutes.	No. of inches Flowed.	Time in Flowing in minutes.	Stationary at Flow in minutes.
8½	4	7½	9	2	1½
1	1	—	½	—	1
—	—	—	½	—	—
1½	—	—	½	—	—
9½	4½	3	9½	4	2 ×
1	3	—	½	—	2
5½	3½	—	7	1	1
½	—	1	—	—	—
3	2	—	4	3	4 Basin 1 inch short of full.
6	3	—	7½	1½	1
6½	3	none	6	1	2½
6½	3½	—	7½	1½	1½ full.
9	4½	2½	9	2	2
9½	4½	5½	9½	3½	1½ ×
½	½	3	—	—	—
1	—	3	—	—	Left it flowing over.
5	2½	none	6½	1½	

Mr. Swainston has favoured me with the following explanatory remarks; which, perhaps, will throw some additional light on the history and properties of Giggleswick Well. In the two observations marked with crosses, the water flowed slowly for the first 3 or 4 inches, and then rose very quickly, until the cistern was full; the same appearance took place not unfrequently in the course of his remarks. Where the blanks are in the columns marked stationary at ebb, the water flowed again instantaneously; but there are some inaccuracies in this part of the table; for Mr. Swainston was interrupted more than once by travellers stopping to let their horses drink. The term stationary at ebb, signifies that the surface of the water in the cistern was stationary at its lowest elevation; at which time the discharge from the trough was commonly confined to the two holes near the bottom of it.

I have now stated all the facts in my possession, that relate to reciprocating springs. The fountains which have been described, are six in number, of these the inconstant brook in Westphalia, appears

to require the agency of a siphon to account for its operations. The characters as ascribed to Pliny's Well, and the well in Dodona, are very ambiguous and unsatisfactory; but the operations of the three remaining springs, and more especially the register of Giggleswick Well, perplex the hypothesis of a siphon with insuperable difficulties; which a superficial inspection of the table will discover to the reader.

The theory, which I shall now propose for the explanation of irregular reciprocating springs, was suggested by an accidental observation; which occurred to Mr. Swainston, whom I have mentioned above. This gentleman, who is a manufacturer of Morocco-leather, has a contrivance in his works, for the purpose of filling a boiler of a particular construction with water. This apparatus consists of a tub, which is considerably elevated above the boiler. The water is conveyed from a pump along a trough into this vessel; from which it runs immediately into the upper extremity of an inverted siphon, which is cemented into a hole in the bottom. This compound tube consists of three branches or legs; the first descends perpendicularly beneath the tub, and is the longest of the three; the second ascends again and carries the water, which comes into it from the first, to a convenient height above the brim of the boiler; the third is a descending leg, which performs the office of nozle, that is, it discharges the water from this crooked canal into the boiler. Mr. Swainston observed by accident, that when the workmen were filling the vessel last-mentioned, the water reciprocated in the tub, the surface of it rising and falling alternately in a manner which he could not explain, by supposing some slight irregularity in the management of the pump. When the appearance was more carefully examined, he found a corresponding variation in the efflux at the nozle; for when the water was rising in the tub, the stream was perceptibly weaker at this outlet, than it was during the ebb or fall of the water in the vessel last-mentioned. He farther observed, that when the water in the boiler rose high enough to cover the end or nozle of the siphon, bubbles of air were seen ascending from this orifice, during the ebb in the tub, or at least during the former part of it; but that they did not appear during the flow, or whilst the water was accumulating in the tub. The fluctuations here described, were far from being regular, either in magnitude or duration; for the water rose much higher in the tub at one time, than it did at

another; and the intervals betwixt flow and flow, or ebb and ebb, were very unequal. In fact the appearances seen in this vessel imitated the caprices and singularities of Giggleswick Well in a natural and surprising manner.

The exact coincidence of the effects, produced by an artificial apparatus, and a noted reciprocating fountain will naturally turn the attention of the curious to inquire into the cause of the irregular motions, which Mr. Swainston observed in his reservoir. The circumstance on which these fluctuations depended, is easily understood; for, seeing the inverted siphon discharged bubbles of air occasionally into the boiler, it is manifest that this subtle fluid entered the tube, mixed with the water, or in other words in the state of foam. Now it is well known, that the bubbles, constituting this frothy substance burst, and the air separates from the water, when the agitation ceases; by which the compound was produced. Such a separation would take place unavoidably in the siphon; because a current flowing in a tube moves on smoothly, or without interruption, which is the cause of agitation. The process here described, discovers the nature of the pheuomena which are exhibited by Mr. Swainston's vessel; for the air, which separates from the water in the siphon, is collected in some part of that tube, most probably in a bend connecting two adjacent legs; where it forms a bubble or mass, large enough to produce a considerable obstruction in the current, by contracting the area of the pipe. The water will evidently rise in the tub, so long as its efflux is interrupted by this obstruction; but the action of the stream in the siphon will push the mass of air from place to place in its own direction until it shall be discharged at the nozle. The removal of this impediment will restore the stream to its full vigour; upon which the water will begin to subside in the tub; and it will continue to do so, until the surface arrives at its proper level; unless a second collection of air happens to be formed in the mean time. We have now investigated the nature of the reciprocation, observable in Mr. Swainston's apparatus, it proceeds entirely from the obstruction of air bubbles, lodged in the crooked canal; the formation of which depends on causes that act in a fortuitous or irregular manner; consequently the reciprocation which results from their united operations will prove to be equally uncertain and variable.

Should the preceding theory of an ebbing and flowing vessel

receive the reader's approbation, he will be disposed to think, that Pliny discovered the true nature of reciprocating fountains, when he compared the fluctuations of these springs to the interrupted and irregular stream which issues from a bottle. In fact, only one circumstance seems wanting to render his explanation of the phenomenon complete; he has not informed his friend Licinius, how he supposes the air gets into the subterranean channel, which supplies his well with water. Perhaps this omission was the effect of design, rather than of negligence; for many philosophers in Pliny's time held the singular opinion, that the earth possesses the faculty of respiration like animals; in consequence of which it inhales and expires air through the crannies and caverns, which extend to its surface. Supposing Licinius to be of this way of thinking, Pliny had no reason to tell this ingenious and learned man, that he imagined the outlet of the fountain had a communication under ground, with one of these spiracles of the globe. Be this as it may, the notion is too absurd to be mentioned in the present improved state of Natural Philosophy, in any other light than as a curious document of the puerile conceits with which the philosophers of ancient times amused their hearers. In the foregoing attempt to complete the theory, I have had recourse to a well known phenomenon; water is beaten into foam by being agitated; which was the case by Mr. Swainston's vessel, because a strong current fell into it from the pump. There is, however, one objection still remaining, which deserves to be considered: the levity of foam, compared with the superior weight of water, may lead some persons to suspect, that this light substance will not mix with water, but will float on the surface of the reservoir, in which it is formed. Supposing this suspicion to be well-founded for the sake of argument, we must allow the foregoing theory of reciprocating vessels to be defective in a very essential point because if foam cannot sink, the air that proceeds from it, cannot find its way into the tubes or siphons, which convey the water from such vessels. Being unwilling to leave this objection unanswered, I resolved to put the truth of this principle to the test of direct experiment; which was done in the following simple manner: A small bell glass, being first filled with water, was inverted in six quarts of the same fluid, contained in a small tub. Things being thus prepared, the contets of the open

vessel were agitated briskly; and the air which entered the water, found its way into the inverted glass, the upper part of which it occupied. The water of the tub was agitated by the motion of a whisk, or a bundle of slender twigs; it was sometimes taken up in a pitcher, and returned into the vessel quickly, from the height of a foot or more; both methods proved successful, but the former appeared to introduce air into the glass with more expedition than the latter did; the difference here mentioned, may however depend entirely upon management and accidental circumstances. The experiment which I have now related, shews the foregoing objection to be of no moment; consequently the present theory of irregular reciprocation may be pronounced to stand upon a safe foundation, and unexceptionable principles.

The observations which have been made on Mr. Swainston's accidental discovery, render an elaborate inquiry into the constitution of Giggleswick well unnecessary. Nature may be easily supposed to have produced an apparatus in the side of the hill, possessing the mechanical properties of the reciprocating tub, and all the phenomena will follow, which are so remarkable in this fountain. Let us imagine a reservoir to be concealed from view under the rocks, into which the stream of a subterranean brook falls, and beats part of its contents into foam by agitation. Let this cavity be connected with the external or visible basin; by a narrow serpentine chink concealed in the interposing strata; and the reader must perceive, without farther explanation, that this conduit will perform the part of the inverted siphon already described, and exhibit the operations, as well as the irregularities of the fountain in question. The same internal structure may be supposed to exist in Lay Well, near Torbay: but something is required, in addition to this simple apparatus, to account for the casual reciprocation of Weeding Well, in Derbyshire. It is not a difficult task to accommodate the theory to the description of this spring; but when we consider how imperfect such descriptions are commonly found to be, it appears more adviseable to pass over this fountain in silence; until some accurate observer shall present the public with a correct and minute history of its operations.

[*Nicholson's Journal, Vol.* 35. *No.* 163.]

6. *Lake Zirknizer, in Carniola.*

This lake was by the ancients called Lugea Palus, by the moderns Lacus Lugeus, though at present its Latin name be Lacus Cirknicensis, in High Dutch Zircknizer sea, and in our Carniolan tongue Zirknisko Jesero. It is at the distance of 6 German miles from the capital city of the province Labac, and is a good German mile long, and about half as much in breadth. Its ordinary depth is 10 cubits, its least 5 or 6, rarely 3, its greatest is 16 cubits. It is every where surrounded with woody mountains, which on the south and west side are very high, and 3 miles broad, running far into the Turkish country, and afford nothing but horrid stony deserts, overgrown with trees.

In the mountain called Javornik, near the lake, there are two holes, or exceedingly deep precipices, in which many thousand wild pigeons roost all the winter; entering in autumn, and coming out with the first of the spring; what they live upon in these caverns is unknown, but perhaps the nitrous sand. On the other hill called Slivenza, is a hole of an unknown depth, out of which there often breathe noxious steams, attended with tempests of thunder and lightning and hail. This lake being every where surrounded with mountains, and nowhere running over, nature has given it two visible channels or stony caverns, by which the water runs under the mountain; and a third concealed subterraneous passage, which without doubt communicates with the other two under ground. This water having run half a German mile, comes out at the other side of the mountain, in a desert place at a stony cave, and forms the river called by the inhabitants Jesero, that is the lake. This river having run half a quarter of a mile enters a wide stony cavern, running slowly under the hill for the space of a good musket-shot, then coming out again on the other side, after it has run through a small plat, it enters a third cavern or grotto; wherein having passed 50 paces, it runs no longer peaceably as before, but with great noise and roaring falls down a very steep channel of stone.

About the feast of St. John Baptist, or St. James tide, and sometimes not till August, the water runs away, and it is dry; but it fills again in October or November; yet so as not to observe any certain time; for sometimes it has been dry twice or thrice in a year,

which makes the fishing very considerable. Sometimes again, though but seldom, it has happened to be 3 or 4 years together full of water, and then is the best of the fishing. But it never yet was observed that this lake was dry for a whole year together.

In this lake there are many pits in the shape of basins or cauldrons, which are not all of the same depth or breadth; the breadth of them being from 20 to 60 cubits, more or less, and the depth from 8 to 20 cubits. In the bottom of these pits are several holes, at which the water and fishes enter when the lake ebbs away. In the months of June, July, and August, when this lake begins to draw off, it grows quite dry in 25 days, if no great rains intervene. And the pits are all emptied one after the other, in a certain and never-failing order of time.

When the lake begins to sink, which appears by a certain stone which they observe, the inhabitants of the town called Oberdorff or Seedorf, give notice thereof to all the neighbouring fishermen, that are appointed by the several lords having right in this fishing. The people of this town have orders not only to watch the falling away of the water, but likewise to take care that nobody presume to fish in the lake when it is full of water, that being forbidden.

The first pit, called Maljoberch, is only a depression of the bottom, without any holes in it; but there grows much grass and weeds, and many fish are caught there. Three days after the water begins to ebb, this pit is emptied. Of this the parish clerk of Seedorf gives notice by tolling a bell, and all the inhabitants of the town, old and young, men and women, lay aside all other business, and go to fishing, quite naked as they were born, without any regard to modesty or shame. The fish they catch they divide in halves, one part they give to the prince of Eggenberg, as the lord of the manor, the other half is their own. The pit Velkioberch is emptied the third day after Maljoberch, the manner and right of fishing as in that. Four hours after this, the pit Kamine begins to empty; here they generally fish with a trawl, as in several other pits of lesser note, having first purchased leave of the lord of the manor. Here, as also in the pit Sueinskajamma, which sinks one hour after Kamine, are many fish caught, and abundance of large crabs, but they are lean and of no good taste. The fifth pit Vodonos, dries five days after Kamine. In this and the other pits which follow, they fish

with a long net or sayne. Here they can have no more than five or six hawls, by reason of the great swiftness with which the water runs away at the holes in the bottom, which is such that a horse can hardly keep pace with it, and carries away the fish with great violence under the earth. Sometimes when the fishermen are not nimble, they can scarcely get two hawls before the water is gone. The pit Louretschka evacuates a day and a half after Vodonos; the fishing is after the same manner, and the same caution necessary, because of the sudden recess of the water. The water leaves the pit Kralouduor 12 hours after Louretschka, and 3 days after that the pit Rescheto. In this latter, in the year 1685, after the lake had been some years without being dry, there were taken at the first hawl 21 carts of fish, at the second 17, and at the third 9. The pit Ribeskajamma falls dry at the same time with Rescheto, which is that next to it. In this pit they fish under ground, which is a curiosity not unpleasant, and differing from all the rest. For there is in the bottom a great hole in the stone, by which men may easily go down with lighted torches, as into a deep cistern; and there is under ground a large cavern like a vault, the bottom or pavement whereof is as it were a sieve full of little holes, whereby the water runs away, leaving the fish dry, where they are caught. The pit Rethje is empty 2 hours after Ribeskajamma, and is of no great consequence for fish. An hour after this, the pit Sittarza, and in 5 or 6 hours more Lipauza falls dry.

The third day after Rescheto the pit Gebno empties; in this they rarely fish with nets, but let it fall dry, and the holes in the bottom being so small, that they exceed not the size of a man's arm, all the great fish are left behind in the pit. Two days after Gebno the pit Koteu becomes dry; in this they sometimes take the fish as in the former, but the holes, being larger, let more fish pass. The pit Ainz empties 4 or 5 hours after Koteu; in this they seldom let the water run away without using their nets, as in Gebno, because of one great hole in the bottom, by which many great fishes may escape. The pit Zeslenza sinks 3 hours after Ainz; in this they always fish with nets, as in Pounigk, which is emptied the next day after Koteu.

The last pit, called Leuische, is evacuated the third day after Pounigk, that is, the 25th day from the beginning of the recess of the water of the lake, so that in 25 days the fishing of this lake is

over. In this last pit, about 17 years since, there fell a flash of lightning, about the time of fishing, which stunned a multitude of large fishes, so as they filled 28 one-horse carts with them. These fish are not properly thunder struck, but only stunned with the violence and sulphureous vapour of the lightning, which makes them rise and swim as dead on the top of the water; but if they be taken up and put in fresh water, they soon recover, otherwise they die; this is no uncommon accident in this lake.

The fishing being thus ended, a signal is given, by tolling the bell in the chapel of St. John the Baptist, near the town of Cirkniz. Upon which all the inhabitants of the neighbouring villages and of Cirkniz, without regard either to age or sex, go mostly quite naked into the lake, and look for fish among the weeds and sedge, and in the smaller pits; and many creep into the subterraneous caverns and passages, and find many large fishes there.

There are, besides these, some other pits in the lake, in which they fish likewise, as also in Mala-karlouza and Velka-karlouza; in both these they go far under ground with lighted torches and find fish. In Velka-bobnarza one may go in at great holes, and descend many fathoms under ground. These two names Velka and Mala-bobnarza signify in the Carniolan tongue the greater and lesser drummer; nor is it without reason that these pits are so called: for when it thunders, there is heard in these two pits as it were the sound of many drums beating.

The two pits Narte and Piauze are never emptied, but always remain fenny, when the rest of the lake is quite dry. It is believed, that in these pits the fish lay their spawn, and therefore it is prohibited to fish in them. In them is an incredible number of horse-leeches. These often stick to the people in the fishing time, some of them being dispersed all over the lake, and the method they take to get them off is to get some other person to make water upon the leech, which makes it let go its hold.

There are in the mountain near the lake, but something higher than it, two great and terrible stony caves, which, though far distant from each other, have yet the same effect, viz. when it thunders, these two caves emit water with a wonderful and incredible force, and with it sometimes a great quantity of ducks with some fish. It is not to be wondered that the lake fills so fast, for considering the violence with which the water rushes, it is like a great

river; this cave being a fathom wide, and higher than a man. It is dangerous to enter into this cave, because the waters come so suddenly, that it is sometimes impossible to escape them.

When it rains moderately, the water spouts with great violence 2 or 3 fathoms perpendicularly out of the pits Koteu and Keslenza. It comes likewise forcibly out of the spring Tresenz, as likewise out of Velkioberch, bringing with it at this latter abundance of fish, and some ducks. But when it rains very hard and long together especially with thunder, then the water breaks out with very great force, not only from all the aforesaid pits, holes, and caves, but likewise at several thousand other little holes, which are all over the bottom of the lake, and which, when the lake is dry, drink up the waters of the eight rivulets that run into it, spouting several fathoms high, from some perpendicularly, from others obliquely, making a very pleasant sight. And out of the pits Vodonos, Rescheto, and some others, having great holes at the bottom, there comes with the water a great quantity of fish. In case of great rains, the eight rivulets running into it are likewise much increased; so that, all things concurring, this lake in 24 hours time will, from quite dry, be full of water, and sometimes in 18 hours; though at other times it has been known to be 3 weeks in filling; but it is a constant observation, that thunder helps much to fill it speedily.

This lake, being thus by turns wet and dry, serves the inhabitants for many purposes. For first, while it is full of water it draws to it several sorts of wild geese and ducks and other water fowl, as herons, swans, &c. which may be shot, and are very good meat. Next, as soon as the lake is emptied, they pluck up the rushes and weeds, which make excellent litter for cattle. Twenty days after it is fully dry, they cut a great quantity of hay upon it. After the hay is off, they plough it and sow millet, which sometimes by the too sudden coming of the water is destroyed, but it generally comes to maturity. While the millet is on the ground, they catch a great number of quails. The millet being off, there is a good pasture for cattle. When the lake is dry, there is great variety of hunting; as there comes out of neighbouring woods and mountains plenty of hares, foxes, deer, swine, bears, &c. as soon as the water is gone. When it is full, one may fish in it. In winter time it will be so firmly frozen as to bear all sorts of carriages, which is a great convenience to the people to fetch their wood and other necessaries.

Lastly. at the time when the water goes away, it yields great abundance of fish, as beforesaid. And that which is most wonderful is, that all this comes to pass in the same place, and the same year, viz. if the lake be early dry, and it fill not too soon; but it is to be noted, that the hay does not grow, nor is the millet sown all over the lake, but only in the more fertile places.

There are only three sorts of fish taken in this lake, which are very well tasted. They are the mustela fluviatilis or eel-pout, some of them weighing 2 or 3 lb.; tench, some of them weighing 6 or 7 lb.; and thirdly, pikes, in very great plenty, of 10, 20, 30, and some of 40lb. weight; in the bellies of these it is common to find whole ducks. Crabs are found no where but in the pits Kamine and Sueinskajamma.

The cause or rather modus of all these wonderful phenomena in the lake of Zirknitz, is probably as follows. There is under the bottom of the lake, another subterraneous one, with which it communicates by the several holes described; there are also some lakes under the mountain Javornik, whose surface is higher than that of the lake Zirknitz. This upper lake is perhaps fed by some of those many rivers, which in this country bury themselves under ground, and has a passage sufficient to carry the waters they bring unto it; but when it rains, especially in thunder showers, which are the most hasty, the water is precipitated with great violence down the steep valleys, in which are the channels of these rivulets; so that the water in this lake, being increased by the sudden coming in of the rains faster than it can empty, swells presently; and finding several holes or caverns in the mountain higher than its ordinary surface, it runs over by them, both into the subterraneous lake under that of Zirknitz, into which the water comes up by the several holes or pits in the bottom of it, as likewise by visible passages above ground.

That some of these passages bring fish, some ducks and fish, others only water, seems to depend on the position of the inward mouths of these subterraneous channels; for if they be so constituted as to draw off the water from the surface of the upper lake, on which the ducks swim, they must needs be drawn away by the stream into these caverns, and come out with the water; but if the channels open into the upper lake under the surface of the water, and from thence ascend obliquely for some space before they come to descend; then the water they carry is drawn from below the

surface, and consequently can bring with it no ducks, but only fish. Those pits which yield only water may well be supposed to be fed by passages too narrow to let the fish pass, though their multitude may make the quantity of water they emit to be very considerable.

The manner of the falling away of the water or emptying of the lake I thus explain: After a long drought, or want of rain, all the springs that feed the upper lake under Javornik are much diminished: so that wanting fresh supplies it ceases to run over by the several channels; hence the lake of Zirknitz, and that under it are fed only by the eight rivulets that always fall into them; and then the water draws off faster than it comes in, both by the channels of Mala and Velkakarlouza, as also by a concealed subterraneous passage out of the under lake, which latter alone is able to transmit more water than the said eight rivulets afford. Consequently the lake must sink, and that in a certain proportion of time, depending on the quantity of water to be evacuated, compared with the excess of that which runs out above what enters it, in the same time. Those pits that are higher are soonest dry, the lower latest, and so come to be emptied in the order above described. And when the lake is all dry, then the said rivulets soak by several very little holes in the bottom into the under lake, and all their water is carried away by the subterraneous passage.

The ducks so often mentioned, and which are cast out with the water, are generated in the lake under the mountain Javornik; when they first come out, they swim well, but are stark blind, and have no feathers on them, or but few, and therefore are easily caught; but in 14 days time they get feathers, and recover their sight yet sooner, and afterwards fly away in flocks. They are black, only white on the forehead; their bodies not large, resembling ordinary wild-ducks, and are of a good taste, but too fat, having near as much fat as lean. I killed some of them as soon as they had been cast out at Sekadulze; and opening their bodies, I found in them much sand, and in some few small fishes, in others green stuff like grass or herbs; which was the more strange, because I never found any green thing growing in any of the subterraneous grottos or lakes in Carniola. Almost every year, at a hole in the mountain called Storseg, about half a German mile from the lake of Zirknitz, near the town of Laas, whenever there happen great floods of rain, this

sort of ducks is cast out in great abundance, by the water gushing out with much force.*

[*Vavasor, Phil. Trans.* 1687.]

SECTION V.

BUBBLING, TEPID, AND BOILING SPRINGS †.

1. *Introductory Remarks.*

HEAT, water and vapours of various kinds, exist in prodigious quantities beneath the surface of the earth; and frequently, as we have already seen in the phenomena of volcanoes and earthquakes, burst forth from enormous jaws or openings, and with tremendous destruction. It often happens, however, that the openings are small and porous, and that the heat or vapours that ascend through them only ascend in a state of union with water. And hence, that almost infinite variety in the characters of those fountains and lakes that are found to be combined with extraordinary materials. In some cases the elastic gasses or vapours ascend from specific levity alone, and destitute of all taste and odour; and we have met with springs that bubble without boiling, or betraying heat or any other foreign property. At other times, they are strongly impregnated with heat; and are then either tepid or boiling, according to the proportion of extricated caloric they contain. And occasionally, whether hot or cold, they are intermixed with metallic, sulphurous, saline or other substances, and hence assume the name of mineral waters: while if the substance thus dissolved be combustible, as naphtha, bitumen or turpentine, the fountain will often inflame and burn upon the application of a lighted torch.

Upon this subject many of the observations offered by Dr. Tancred Robinson in the Philosophical Transactions, are worthy of at-

* There is another, but a less scientific account of the same lake given in the same journal, by Dr. Brow[illegible] Vol. IV. year 1669.—The reader will also meet with other instances of ebb[illegible] [illegible]owing waters in the ensuing sections; and especially in section x, Int[illegible] [illegible]emarks; and section xi. Lake Jezero.

† For other instances, the re[illegible] turn to the two ensuing sections.

tention, and especially the following, which we copy from the abridged edition *.

"The water of the noted boiling fountain at Peroul, near Montpelier, is observed to heave and boil up very furiously in small bubbles; which manifestly proceed from a vapour breaking out of the earth, and rushing through the water, so as to throw it up with noise, and in many bubbles; for upon digging any where near the ditch, and pouring other water on the dry place newly dug, the same boiling is immediately observed. The like bubbling of water is also found round about Peroul on the sea shore, and in the Etang itself. In order to discover the cause of this odd phenomenon, Dr. Robinson took some of the sand and earth out of the fountain and ditch, putting it into vessels, and pouring some of the same water upon it, there did not appear the least commotion or alteration; the surface of the water continuing very smooth, equal, and quiet. On further search, he discovered in several dry places of the ground thereabouts, many small venti-ducts, passages, or clefts, where the steam issued forth; at the mouths of these pipes, placing some light bodies, as feathers, small thin pieces of straws, leaves, &c. they were soon removed away. This vapour, on the application of a lighted candle or torch, did not flame or catch fire in the least, as the fumes running through a boiling spring near Wigan in Lancashire do, as noted in the Philos. Trans. N° 26; so that here we have two different sorts of steams causing these boilings, yet neither of the fountains are medicinal, nor so much as warm: the like is related by Varenius, near Culm, and by Dr. Plott in England. There are other boiling waters, of a quite contrary temper, being actually hot to several degrees, so as to boil eggs and many other things, put into them; as those near the Solfatara not far from Naples; as also on the top of Mount *Zebio* in the Duke of Modena's territories, not far from his villa near Sassolo; and in the source of the Emperor's bath at Aix la Chapelle, in the duchy of Juliers. Varenius tells us, that in Japan there bursts out a boiling spring, so hot that no water can be heated so much by the strongest fire; that it retains its heat three times longer than common water; and that it does not flow continually, but for two hours each day; and then the force and violence of the vapours are so great, that they remove

* Vol. III. p. 136,

large stones, and raise them to the height of 3 or 4 ells, with a noise like the explosion of a great gun.

From the foregoing history, we may take occasion to reflect a little on the variety of exhalations prepared in and flying out from the vast subterraneous magazines and repositories, as to their qualities and effects, some being cold and dry, resembling air or wind, as those near Peroul, and in the caverns of mountains, especially those of Æolus, and other hills of Italy, as also in mines; others are inflammable, and of a bituminous nature, though not actually warm, as those near Wigan in Lancashire; there are also many steams very hot, sulphureous, and saline, more especially those in the natural stoves, sweating vaults, grots, baths, and the volcanos near Naples, Bajæ, Cuma, and Puzzuolo, as also in some of the subterraneous works at Rome; others there are of an arsenical and such like noxious qualities, as in the Grotta del Cane, on the bank of the Lago Agnano; in several mines, and in poisonous springs and lakes. Now these various steams meeting with, and running through waters, must cause a great variety of phænomena and effects in them."

Many of these depend obviously upon the agency of volcanos, and are immediately connected with them. There are many hot springs, however, whose temperature is too equable, and which occur at too great a distance from any known volcanos to be produced by them. "Thus the hot-spring at Bath," observes Dr. Thomson *, has continued at a temperature higher than that of the air for a period not less than 2000 years; yet it is so far from any volcano, that we cannot, without a very violent and improbable extension of volcanic fires, ascribe it to their energy. There are various decompositions of mineral bodies, which generate considerable heat. These decompositions are usually brought about by means of water; or, to speak more properly, water is itself the substance which is decomposed, and which generates heat by its decomposition. Thus, for example, there are varieties of pyrites, which are converted into sulphate of iron, by the contact of water, and such a change is accompanied by an evolution of heat. Were we to suppose the Bath spring to flow through a bed of such pyrites, its heat might be occasioned by such a decomposition. Such, probably, is

* History of the Royal Society, b. I. ch. iii.

the way in which those mineral springs, that contain sulphureted hydrogen gas, receive their impregnation. But we are pretty certain, that such a supposition will not apply to Bath water: first, because it does not contain the notable quantity of sulphate of iron, which would be necessary upon such a supposition; and, secondly, because instead of sulphureted hydrogen gas, which would infallibly result from such a decomposition of pyrites, there is an evolution of azotic gas. This evolution of azotic gas, however, is a decisive proof that the heat of Bath waters is owing to some decomposition or other, which takes place within the surface of the earth; though, from our imperfect acquaintance with the nature of the mineral strata, through which the water flows, we cannot give any satisfactory information about what that decomposition actually is."

EDITOR.

2. *On the Temperature of the Earth below the Surface, in regard to Springs and Hills, and especially those of Jamaica.* By John Hunter, M.D. F.R.S.

" The great difference, says Dr. H. between the temperature of the open air, and that of deep caverns or mines, has long been taken notice of, both as matter of curiosity and surprize. After thermometers were brought to a tolerable degree of perfection, and meteorological registers were kept with accuracy, it became a problem, to determine what was the cause of this difference between the heat of the air and the heat of the earth; for it was soon found that the temperature of mines and caverns did not depend on any thing peculiar to them; but that a certain depth under ground, whether in a cave, a mine, or a well, was sufficient to produce a very sensible difference in the heat. In observations of this kind, there was perhaps nothing more striking, than that the heat in such caves was nearly the same in summer and winter; and this even in changeable climates, that admitted of great variation between the extremes of heat in summer, and cold in winter. There is an example of this in the cave of the Royal Observatory at Paris. The explanations, which have been attempted of this phænomenon, have turned chiefly on a supposition, that there was an internal source of heat in the earth itself, totally independent of the influence of the sun *. M. de Mairan has bestowed much labour on this subject, and by obser-

* Vid. Martine's Essays, p. 319.

vation and calculation is led to conclude, that of the 1026° of heat, by Reaumur's scale, which he finds to be the heat of summer at Paris, 34°.02 only proceed from the sun, and the remaining 991°.98 from the earth, by emanations of heat from the centre *. The proportion therefore of heat derived from this latter source is to that of the sun, as 29.16 to 1. It must be evident that an hypothesis of this kind, which renders the influence of the sun of small account, is directly contrary to the general experience and conviction of mankind. Without entering however into any discussion of the data from whence M. de Mairan draws his conclusions, it will be more satisfactory to consider what would be the effect of the operation of those laws of heat with which we are acquainted.

And first, it is well known, that heat in all bodies has a tendency to diffuse itself equally through every part of them, till they become of the same temperature. Again, bodies of a large mass are both cooled and heated slowly. Besides the mass of matter, there are two other considerations of much importance in the slow or quick transmission of heat through bodies; these are their different conducting powers, and their being in a state of solidity or fluidity. The conducting powers of heat are well known to be very various in different bodies; nor are they hitherto reducible to any law, depending either on the density or chemical properties of matter. Metals of all kinds are good conductors of heat, while glass, a heavy, solid, homogeneous body, is an extremely bad conductor, even when a metallic calx enters largely into its composition, as in flint-glass. A state of fluidity greatly promotes the diffusion of heat; for a body in a fluid state, by the particles moving readily among each other from their different densities or other causes, mixes the warm and cold parts together, which occasions a quick communication of heat. To apply these observations to the present subject; the surface of the earth being exposed to the great heats of summer, and the colds of winter, or more properly the low degree of heat of winter, will receive a larger proportion of heat in the former season, and a smaller in the latter; and being further of a large mass, and of a porous and spongy substance, and therefore not quickly sensible to small variations of heat, it will become of a mean temperature at a certain depth, between the heat of summer and the cold of winter, provided it contain no internal source of

* Memoir de l'Acad. des Sciences, An. 1719 et 1765.

heat within itself. This conclusion is strictly agreeable to the experiments and observations hitherto made, in heating and cooling bodies, or in mixing portions of matter of the same kind of different temperatures *. Water, though in a large mass, follows in some degree the heat and cold of our summer and winter, from the mobility of its parts occasioning a more speedy diffusion of heat. Air is quickly susceptible of heat, and from the expansions produced in it, and consequent motions in the whole mass, the temperature is soon rendered uniform.

The changes in the heat of the air are what we have measured, and we are to be understood to speak of them, when we talk of the temperature of summer and of winter. It may be asked then, is the heat of the sun first communicated to the air, and thence to the earth? No, the air is susceptible of a very small degree of heat from the rays of the sun passing through it; for it is well known that they produce no heat in a transparent medium, and consequently, that the air is only so far heated as it differs from a medium that is perfectly transparent. The heat produced by the rays of the sun bears a proportion to their number, their duration, and their angle of incidence; and it takes place at the points where they strike an opaque and non-reflecting surface. The surface of the earth may therefore be considered as the place from which the heat proceeds, which is communicated to the air above, and the earth below. That this is really the case, is evident from the superior degree of heat produced by the action of the rays of the sun on an opaque body, which will often be heated to 150° of Fahrenheit, while the temperature of the air is not above 90° †. It may seem, therefore, that to measure the heat communicated to the earth, it should be done at the surface, where the action of the rays immediately takes place. But though the heat be produced at the surface, it is communicated freely to the air as well as the earth; and though the apparent intensity of heat be greater in the earth, from the rays of light acting for a longer time on the same parts of matter, yet, there is little doubt that much the greater part is carried off by the air, which as it is heated flies off, and allows a fresh portion of cold air to come in contact with the heated surface. But still it

* De Luc Modifications de l'Atmosphere, vol. I. p. 385.
† Martine's Essays, p. 309.

is immaterial, whether the heat of the sun be excited more in the earth or in the air; for whichever has the larger proportion will in the end communicate a part to the other, and so restore the balance. The same observation applies to such causes of cold as may operate at the surface of the earth, as evaporation, &c. The air therefore, near the surface of the earth, will show by a thermometer in the shade nearly, if not exactly, the same degree of heat that the sun communicates to our terrestrial globe; and if a mean of the heats thus shown be taken for the year round, and we penetrate into the earth to that depth, that it is no longer affected either by the daily, monthly, or annual variations of heat, the temperature at such depth should be equal to the annual mean above mentioned. To ascertain this with the utmost precision, it must be obvious that numerous observations should be made every day, corresponding to the frequent changes of temperature, which are known to happen in the course of 24 hours in all climates; and on these a daily mean should be taken, and the annual mean deduced from them. This has not yet been done, but where we have observations from which a mean temperature can be deduced with any degree of certainty, it will be found not to differ greatly from the heat of deep caves, or wells in the same climate.

For obtaining the temperature of the earth, the best observations are probably to be collected from wells of a considerable depth, and in which there is not much water. Springs issuing from the earth, though indicating the temperature of the ground from which they proceed, are not so much to be depended on as wells; for the course of the spring may be derived from high grounds in the neighbourhood, and it will thence be colder; it may run so near the surface as to be liable to variations of heat and cold from summer and winter; or it may be exposed to local causes of heat in the bowels of the earth. Wells seem also better than deep caverns, for the apertures to such are often large, and may admit enough of the external air to occasion some change in their temperature. Wells are not however to be met with in all places, and in that case we must remain satisfied with the temperature of the springs.

The following observations were made in the island of Jamaica, where there are flat lands in many parts towards the coast, but all the interior part of the country is mountainous. The heat is greatest in the low lands, and decreases as you ascend the mountains. The

town of Kingston is supplied with water from wells. The ground on which it stands rises with a gentle ascent as you recede from the sea. In the low part of the town the wells are but a few feet deep, and many of them brackish. The heat of the water in some of them I have found as high as 82°; but they were evidently too near the surface not to be affected by the heat of the seasons. As you ascend, the wells are deeper, and the temperature is nearly 80° in all of them. What variations there are, come within 1°, that is, half a degree less than 80°, or half a degree more. They are of different depths, and some not less than 100 feet; though, after they are of half that depth, the temperature is nearly uniform. At the Governor's Pen, which is also in the low part of the country, a well, which is above 60 feet deep, is $79\frac{1}{2}$°. There is a well at Half-way-tree, 243 feet deep, which is 79°. Half-way-tree is two miles from Kingston, with a very gentle ascent. Near Rock-Fort is a spring, immediately at the foot of the long mountain, which throws out a great body of water; the heat of it is 79°. All the places mentioned are but very little above the level of the sea, probably not more than the depth of the wells at the respective places; for near Kingston there are springs that appear just below the water-mark of the sea, and those that supply the wells are probably on the same level.

The temperature of the air at Kingston admits but of small variation. The thermometer, at the hottest time of the day, and during the hottest season of the year, ranges from 85° to 90°; in the coolest season, and observed about sun-rise, which is the coldest time in the 24 hours, it ranges from 70° to 77°. I have seen it once as low as 69°, and two different times as high as 91°. The annual mean temperature cannot therefore either much exceed, or fall much short of 80°, as indicated by the wells.

The following springs were examined with much accuracy by the Hon. Mr. Sewell, Attorney-General of the island. Ayscough's spring, on the road from Spanish Town to Pusey's, in St. John's parish, 75°. Pusey's spring, still higher in the mountains, $72\frac{3}{4}$°. A spring near the barracks, at Points hill in St. John's parish, 70°. The thermometer in the shade at Pusey's, during part of the month of June, was found to range from $69\frac{1}{2}$° to $79\frac{1}{2}$°. It was observed both late at night and early in the morning before sun-rise. The spring in Brailsford Valley, about 10 miles above Spanish

Town, is 75°. The spring at Stoney Hill is 71°. These were examined by Mr. Home.

Mr. Wallen's house, at Cold Spring, stands the highest of any in the island. By a measurement said to have been made by Mr. M'Farlane, it is reported to be 1400 yards above the level of the sea. On the road to it, and about a mile below Mr. Wallen's house, there is a spring that issues from the side of the hill, of the temperature of 65°. Cold Spring, which gives a name to the place, is about 50 feet below the house, and the heat of it is 61¾°. The thermometer in the shade at Mr. Wallen's house, for some days in the month of April, ranged from 57° to 67°. It may be remarked, that the higher the springs the colder the air; and as far as a conjecture can be formed from so few observations, they would appear not to differ much from the mean temperature of their respective places.

It will not be out of place to add some observations made in England, relative to the same subject. The wells in and about London are either of no great depth, or are full of water, which are both considerable objections to their giving a mean temperature. The want of depth will make them subject to the variations of the seasons; and a large quantity of water, even in a deep well, will take the temperature of the air more or less: for any change of temperature communicated at the surface will, from the fluidity of the water, be readily diffused through the whole. It is probably owing to this cause, that the wells in the neighbourhood of Brighthelmstone vary from 50° to 52°, for those were the highest that had the most water in them. The observations were made in summer. These wells are of various depths, from 15 to 150 feet. That which is always found the coldest is not more than 22 feet deep; its heat was never greater than 56°. It is near the beach, and is a tide well, that is, the water in it rises and falls, and yet does not correspond exactly with the tides, but follows them with an interval of about three hours. At the lowest there is not more than a foot of water in it; and it may be considered as a subterraneous spring running through the bottom of the well. There are in fact numerous springs that break out on the sand, a few feet above the low-water mark, which are doubtless the same that supply the wells. As we are not acquainted with any cause that produces cold in the bowels of the earth, we must necessarily,

in every climate, consider the lowest degree of heat as approaching nearest to the mean temperature; and therefore we cannot conclude the mean temperature at Brighthelmstone to be more than 50°. The mean temperature of London is computed about 52°; Brighthelmstone is nearly 50 miles farther south than London, and is immediately on the sea, and must therefore be at least as warm as London. It is evident that the observations from which the mean is taken, must generally contain more of the extremes of heat than of cold, as the former happen in the day-time, and the latter in the night, in consequence of which they will often escape notice. There is a table, next following this paper, constructed by Dr. Heberden, expressing the heat in London for every month in the year, from a mean of ten years, beginning with 1763, and ending with 1772. The mean temperature is given both at 8 A. M. and 2 P. M. There is further in the table, a column of the mean of the greatest monthly colds in the night, observed during the same 10 years by Lord Charles Cavendish, in Marlborough-street. There will not probably be any great error in considering the heat observed at 2 P. M. as the greatest daily heat; and taking a mean between the greatest heats of the day, and greatest colds of the night, they give 49°.196 for an annual mean, which is much lower than is commonly supposed. At the house of George Glenny, Esq. near Bromley, there is a well 75 feet deep, which in November was $49\frac{1}{2}$°. M. de Mairan has given a table of the greatest heats and greatest colds observed at Paris for 56 years, beginning from 1701; and a mean of them is 10° above freezing, or 1010° of Reaumur's scale*. The temperature of the cave of the Observatory where those observations were made, is $10\frac{1}{4}$° above freezing, by the same scale of Reaumur. There appears not therefore any necessity for an internal heat; on the contrary, it is matter of demonstration, that were there any source of heat in the earth which was not equally in the air, the heat of the interior parts ought to be higher than a mean: and if the central heat bore as high a proportion to that of the sun as M. de Mairan alledges, the heat of the earth itself ought to be a great deal above the mean temperature of the air, which from observation there is no ground for

* Mem. de l'Acad. des Sciences, An. 1765, p. 202.

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believing. It is easy to see the source of M. de Mairan's error; he has founded his calculations on the scale of Reaumur, and considers the degrees of his thermometer as marking the real proportions, and absolute quantity of heat. It is a matter that cannot be denied, that we know nothing of the absolute quantities of heat; and that the degrees of the thermometers are only to be considered as a few of the middle links of a chain, the length of which we are totally ignorant of, and therefore in no condition to compare its proportional parts. It deserves however to be remarked, that the observations of a late date have shown, that the notions of cold on which Reaumur's scale was constructed, and on which M. de Mairan's calculations are founded, are imaginary and without foundation.

The sea admits of change of temperature more quickly than the earth, particularly near the shore. The mean heat of the sea at Brighthelmstone, during the months of July, Aug. Sept. and Oct. was as annexed:

July	$63\frac{1}{2}°$
Aug.	$63\frac{1}{2}°$
Sept.	58°
Oct.	53°

The wells at New York are from 32 to 40 feet in depth, and Dr. Nooth found them to have an annual variation of 2°, from 54° to 56°. There are few countries, in which the annual range of the thermometer is greater than at New York, and the neighbouring parts of America. In the summer it is often as high as 96°, and in winter it has been observed several degrees below the zero of Fahrenheit's scale. On the whole, we may, from all the observations we are yet in possession of, conclude, that there is at present no source of heat in the earth, capable of affecting the temperature of a country, which is not derived from the sun; and that the earth whatever changes of temperature it may be conjectured to have undergone in former periods, is now reduced to a mean of the heat produced by the sun in different seasons, and in different climates. [*Phil. Trans. Abr. Vol.* xvi.

3. *The Caldeira of St. Michael.*

To this island we have already had occasion to allude to on another account. We shall now return to it in order to describe its tepid and hot springs, which we cannot possibly do more correctly than in the following extract from a paper of Mr. Francis Masson, inserted in the Journal of the Royal Society.

About four leagues north-east from Villa Franca lies a place called the Furnas, being a round deep valley in the middle of the east part of the island, surrounded with high mountains, which though steep, may be easily ascended on horseback by two roads. The valley is about five or six leagues in circuit; the face of the mountains, which are very steep, is entirely covered with beautiful evergreens, viz. myrtles, laurels, a large species of bilberry, called uva de serra, or mountain grapes, &c. and numberless rivulets of the purest water run down their sides. The valley below is well cultivated, producing wheat, Indian corn, flax, &c. The fields are planted round with a beautiful sort of poplars, which grow into pyramidal form, and by their careless, irregular disposition, together with the multitude of rivulets, which run in all directions through the valley, a number of boiling fountains, throwing up clouds of steam, a fine lake in the south-west part about two leagues round, compose a prospect the finest that can be imagined. In the bottom of the valley the roads are smooth and easy, there being no rocks but a fine pulverized pumice stone that the earth is composed of.

There are a number of hot fountains in different parts of the valley, and also on the sides of the mountains: but the most remarkable is that called the Caldeira, situated in the eastern part of the valley, on a small eminence by the side of a river, on which is a bason about 30 feet diameter, where the water continually boils with prodigious fury. A few yards distant from it is a cavern in the side of the bank, in which the water boils in a dreadful manner, throwing out a thick, muddy, unctuous water, several yards from its mouth, with a hideous noise. In the middle of the river are several places where the water boils up so hot, that a person cannot dip his finger into it without being scalded; also along its banks are several apertures, out of which the steam rises to a considerable height, so hot that there is no approaching it with one's hand: in other places, a person would think, that a hundred smiths' bellows were blowing together, and sulphureous streams issuing out in thousands of places, so that native sulphur is found in every chink, and the ground covered with it like hoar frost; even the bushes near these places are covered with pure brimstone, condensing from the stream that issues out of the ground, which in many places is covered over with a substance like burnt alum. In these

small caverns, where the steam issues out, the people often boil their yams (inhames). Near these boiling fountains are several mineral springs; two, in particular, whose waters have a very strong mineral quality, of an acid taste and bitter to the tongue.

About half a mile to the westward, and close by the river side, are several hot springs, which are used by sick people with great success. Also on the side of a hill, west of St. Ann's church, are many others, with three bathing houses, which are most commonly used. These waters are very warm, though not boiling hot; but at the same place issue several streams of cold mineral water, by which they are tempered, according to every one's liking. About a mile south of this place, and over a low ridge of hills, lies a fine lake about two leagues in circumference, and very deep, the water thick, and of a greenish colour. At the north end is a plain piece of ground, where the sulphureous streams issue out in many places, attended with a surprising blowing noise. The other springs immediately form a considerable river, called Ribeira Quente, or hot river, which runs a course about two or three leagues, through a deep rent in the mountains, on each side of which are several places where the smoke issues out. It discharges itself into the sea on the south side, near which are some places where the water boils up at some distance in the sea.

This wonderful place had been little noticed till very lately; so little curiosity had the gentlemen of the island, that scarcely any of them had seen it, till of late some persons afflicted with virulent disorders, were persuaded to try its waters, and found immediate relief from them. Since that time it has become more and more frequented; several persons who had lost the use of their limbs by the dead palsy have been cured; and also others who were troubled with eruptions on their bodies. A clergyman, who was greatly afflicted with the gout, tried the said waters, and was in a short time perfectly cured, and has had no return of it since. Several old gentlemen who were quite worn out with the said disorder, were using the waters, and had received great benefit from them; in particular, an old gentleman about 60 years of age, who had been tormented with the disorder more than 20 years, and often confined to his bed for six months together; having used these waters about thee weeks, had quite recovered the use of his limbs, and walked about in great spirits. A friar also who had been troubled with

the said disorder about 12 years, and reduced to a cripple, by using them a short time was quite well, and went a hunting every day. There are several other hot springs in the island, particularly at Ribeira Grande; but they do not possess the same virtues, at least not in so great a degree. [*Phil. Trans. Abrid.* 1778.

4. *Hot Springs in the District of Troas.*

After having passed the ford, we gallopped up to the Agha's mansion at Bonarbashy, the name of which place, literally translated, signifies '*The head of the springs* *.' Immediately on my arrival, I hastened to them, keeping a thermometer exposed and pendent the whole way, as the sun was then setting, and a favourable opportunity offered for an accurate investigation of their temperature. Some peasants who conducted me, related the tradition concerning the supposed heat and cold of the different sources; *one* only being, as they said, a hot spring. I desired to examine that first, and for this purpose was taken to a place about half a mile from the Agha's house; to the most distant of the several springs; for in fact there are many, bursting from different crevices, through a stratum of *breccia*, or pudding stone, covered by a superincumbent layer of lime-stone. From the number of the springs, the Turks call the place *Kirk Guese*, or '*Forty Eyes*.' I then asked the peasants if this was the hot spring, as it evidently was not the same described by Monsieur Chevalier. They replied that its greatest heat might be observed during winter, and therefore that it must be now hot †. It was a shallow pool of water, formed by the united product of many small streams, issuing from several cavities in the rock I have mentioned. This pool was quite overshadowed by some distant hills, behind which the sun was then setting; it was therefore a proper time for ascertaining the temperature, both of the air and the water. A north wind had prevailed during

* Places are named in Wales exactly after the same manner; as Pen tre fynnyn, '*The head of the three springs*.'

† Almost the only winter the Turks had in 1801 was during the month of March. The peasants believe the heat to be greater at that season of the year, merely because the external air is colder. The temperature of the water is always the same.

the day, but the sky had been more than usually serene, and without a cloud: not a breath of air was then stirring. I first tried the water with my hand; it felt warm, and even the rock near and above the surface of the water was sensibly affected by heat. I then had recourse to my thermometer; it was graduated according to the scale of Celsius; but I shall give the result according to the corresponding elevation of Fahrenheit; being more adapted to common observation in England. When exposed to the external air the mercury stood at 48°; or sixteen degrees above the freezing point. I then placed it in one of the crevices whence the water issued, so as to immerse both the tube and scale: in two minutes, the mercury rose to 62°, and there remained. I then tried the same experiment in all the other crevices, and found the heat of the water the same, although the temperature of the external air was lowered to 47°. From thence I proceeded to the hot spring of M. Chevalier; and could not avoid being struck by the plausible appearance it offered, for those who wished to find here a hot and cold spring, as fountains of the Scamander. It gushes perpendicularly out of the earth, rising from the bottom of a marble and granite reservoir, and throwing up as much water as the famous fountain of Holywell in Flintshire. Its surface seems vehemently boiling; and during cold weather, the condensed vapour above it causes the appearance of a cloud of smoke over the well. The marble and granite slabs around it are of great antiquity; and its appearance in the midst of surrounding trees, is highly picturesque. The mercury had now fallen, in the external air, to 46°, the sun being down; but when the thermometer was held under water, it arose as before, to 62°. Notwithstanding the warmth of this spring, fishes were seen sporting in the reservoir. When held in the stream of either of the two channels which conduct the product of these springs into a marsh below, the temperature of the water diminished, in proportion to its distance from the source whence it flowed. I repeated similar observations afterwards, both at midnight, and in the morning before sun-rise; but always with the same results. Hence it is proved, that the fountains of Bonarbashy are warm springs; of which there are many, of different degrees of temperature in all the district through which the Mender flows, from Ida to the Hellespont. That the two channels which convey

Engraved by Hay from a Drawing by Craig

For the Gallery of Nature & Art

THE GREAT GEYSER, OR BOILING SPRING OF
Haukadal in Iceland.

London. Published by [illegible] Miller [illegible]

them towards the Scamander may have been the ΔΟΙΑΙ ΠΗΓΑΙ of Homer *, is at least *possible:* and when it is considered, that a notion still prevails in the country, of one being hot, and the other cold; that the women of the place bring all their garments to be washed in these springs, not according to the casual visits of ordinary industry, but as an antient and established custom, in the exercise of which they proceed with all the pomp and songs of a public ceremony; it become perhaps *probable* †.

[*Clarke's Travels to Greece, Egypt, and the Holyland.*

5. *Hot Springs in Iceland.*

In a Letter from John Stanley, Esq. M. P. F.R.S. &c. to Dr. Black.

1. *Reykam Springs.*

You received two kinds of water, one from a spring near a farm called Rykum and the other from the fountain known by the name of the Geyzer, the most remarkable in the island. It rises near the farm of Haukadale, about forty miles from Rykum. They are both situated in the S. W. division of the island.

I shall begin with a description of the country and the springs near Rykum, and of the first view we had of them in our way from Rykavick to Mount Hecla. Rykum is situated in a valley, which, on account of its fertility, and the strong contrast it made with the dreary scenes we had passed since our last station, appeared to us with great advantage while we approached it. We had traversed a country, seven or eight miles in breadth, entirely overspread with lava, and other volcanic matter. It was surrounded with hills, not sufficiently high to be majestic, and too rugged and too barren to be pleasnig. We were told by our guides, that, on a clear day, the summits of Hecla might be seen above those which

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* The following is a literal translation of the words of the Venetian Sholiast, upon Il. X'. 148. " Two fountains *from* the Scamander rise in the plain; but the fountains *of* the Scamander are not in the plain.

† The full description of such a ceremony occurs in the sixth book of the Odyssey, where it is related, that the daughter of Alcinous, with all the maidens of her train, proceeds to wash the linen of her family. According to Pausanias, there was an ancient picture to be seen in his time, in which this subject was represented.

were immediately before us; but heavy and lowering clouds, which threatened us incessantly with a storm, concealed every distant object from our sight.

We saw many districts in Iceland covered with lava; but I do not recollect one so uncouth and desolate as this. No vegetation was to be seen but that of a few stunted bushes of willow and birch, growing between the crevices and hollows of the lava, into which the wind had drifted sufficient soil for them to take root. We could discover no mount or crater from whence we could conjecture, with any degree of probability, the lava to have issued. It extended round us like a sea; and it had burst perhaps from some part of the country it now covered, while the fire to which it owed its origin, had escaped with its showers of cinders and ashes, from some other orifice, and had formed one of the numberless cones we could discover amidst the neighbouring hills.

The unpleasantness of our ride over this country was increased by the continual danger to which we were exposed of our horses falling. The road was no other than what the few travellers of the country, as they passed from their farms to Rykavick, had tracked over the lava where it was least rough; but even this was interrupted by many breaks and crevices, formed by the cooling of the matter and the contraction of its parts .

To this uncomfortable scene succeeded the view of a rich valley, opening into an extensive green plain bounded by the sea. A river was seen winding between several fertile meadows; and beyond these, the valley was terminated by a range of high and bold rocks. But our attention was chiefly attracted by the clouds of steam, which ascended in various parts of the valley from the hot springs, and by jets of water, which, from some of them, were incessantly darted into the air.

We descended into the valley by a road winding over the lava, which, in one place, had flowed from the upper plain into the country below. On which side it had stopped abruptly, and had thus formed a perpendicular wall, at least sixty feet high.

We pitched our tents in a pleasant field, on the side of the river, opposite to the farm, and not far from it, and at the foot of the hills which bounded the valley. Several fragments of rocks, which had fallen from these, lay scattered round our station. These were entirely volcanic; some of dark blue lava, not unlike basalte;

others of a yellow substance; and again others of a gray lava, mixed with a great quantity of white glass: But the most curious consisted of an heterogeneous mixture of various substances, cemented indiscriminately together by some operation, subsequent to their original formation, and so strongly that the rock was broken with difficulty by our hammers. It consisted of pieces of black glass (a lava in all probability much vitrified), and large pieces of a close, gray lava, the cavities and pores of which were filled with zeolites finely radiated. Some pieces of black lava, in parts compact, and in other parts so porous as to approach nearly to a pumice stone, were mixed with the rest of the mass. A mixture of the same substance, (the lavas, the glass and the zeolites), pounded in small grains filled the spaces between the larger pieces, and connected the whole into a solid rock. The heat (if heat it was) which had cemented these materials, had not been strong enough to reduce any one to a state of fusion; for the angles of the fragments were as sharply defined as if newly separated from their respective original beds.

The rocks from whence these different masses have been detached, lay heaped together in so disjointed and irregular a manner that some violent convulsion has evidently taken place among them since their first formation; but similar appearances of disorder are to be seen in every range of hills in the country. Regular strata are no where to be met with. It appears as if all this part of the island, at different periods, had been thrown up from its foundations.

The valley is in this place fertile, and nearly half a mile in breadth. It becomes more narrow towards the north; and it is there rendered barren by heaps of crumbled lava, or other rubbish, brought down from the hills by waters. These have the appearance of artificial mounds, and a great number of springs are continually boiling through them. Below the surface, a general decomposition seems taking place; for almost whenever the ground is turned up, a strong heat is felt, and the loose earth and stones are changing gradually into a clay or bole of various colours and beautifully veined, resembling a variegated jasper. The heat may possibly proceed from a fermentation of the materials composing these mounds; but more probably (I should conjecture) from the springs and steam forced up through them. The springs must have

acquired their heat at some greater depth, from some constant, steady cause, (however difficult to explain) adequate to the length of time they have been known to exist, with the same unvaried force and temperature.

Springs do not boil on or near these banks only. They rise in every part of the valley, and within the circumference of a mile and an half, more than an hundred might easily be counted. Most of them are very small, and may be just perceived simmering in the hole from whence the steam is issuing. This, trailing on the ground, deposits in some places a thin coat of sulphur. The proportion varies; for near some of these small springs, scarce any is perceptible, whilst the channels by which the water escapes from others, are entirely lined with it for several yards. Neither the water, nor the steam from the larger springs, ever appear to deposit the smallest proportion of sulphur; nor can the sulphureous vapour they contain be discovered, otherwise than by the taste of what has been boiled in them for a long time.

Many springs boil in great cauldrons, or basons, of two, three or four feet diameter. The water in these is agitated with a violent ebullition, and vast clouds of steam fly off from its surface. Several little streams are formed by the water which escapes from the bason; and as these retain their heat for a considerable way, no little caution is required to walk among them with safety.

The thermometer constantly rose in these springs to the 212th degree; and in one small opening, from whence a quantity of steams issued with great impetuosity, Dr. Wright observed the mercury rise, in two successive trials, to the 213th degree.

I have already said, that the ground, through which many of the springs are boiling, was reduced to a clay of various colours. In some, the water is quite turbid; and, according to the colour of the clay through which it has passed, is red, yellow or gray.

The springs, however, from whence the water overflows in any great quantity, are to appearance perfectly pure. The most remarkable of these was about fifty or sixty yards from our station, and was distinguished by the people of the neighbourhood, by the name of the little Geyzer. The water of it boiled with a loud and rumbling noise in a well of an irregular form, of about six feet in its greatest diameter; from thence it burst forth into the air, and subsided again, nearly every minute. The jets were dashed into

spray as they rose, and were from twenty to thirty feet high. Volumes of steam or vapour ascended with them, and produced a most magnificent effect, particularly if the dark hills, which almost hung over the fountain, formed a back ground to the picture. The jets are forced in rising to take an oblique direction, by two or three large stones, which lie on the edge of the bason. Between these and the hill, the ground (to a distance of eight or nine feet) is remarkably hot, and entirely bare of vegetation. If the earth is stirred, a steam instantly rises, and in some places it was covered with a thin coat of sulphur, or rather, I should say, some loose stones only were covered with flakes of it. In one place, there was a slight efflorescence on the surface of the soil, which by the taste, seemed to be allum.

The spray fell towards the valley, and in that direction covered the ground with a thick incrustation of matter which it deposited. Close to this, and in one spot very near the well itself, the grass grows with great luxuriance.

Where the soil was heated, it was gradually (as on the mounds) changing into a clay. But it was here more beautiful than in any other place. The colours were more varied and bright, and the veins were marked with more delicacy. The transition likewise from one substance into the other, was more evident and satisfactory.

To the depth of a few inches, the ground consisted of loose lavas, broken and pounded together, of blue, red and yellow colours. The blue lava was hardest; and several pieces of it remained firm and unaltered, while the rest were reduced to a dust. The colours became brighter as the decomposition of the substances advanced, and they were changed at the depth of nine or ten inches into a clay; excepting, however, the pieces of dark blue lava, which still ratained sufficient hardness to resist the pressure of the finger. Round these which appeared insulated in the midst of the red and yellow clay), several veins or circles were formed of various shades and colours. A few inches deeper, these also became part of the clay, but still appearing distinct, by their circles, from the surrounding mass. The whole of this variegated substance rested on a thick bed of dark blue clay, which had evidently been formed in the same manner from some large fragment of blue lava, or stratum of it, broken into pieces.

The resemblance of these clays to jasper is so striking to the eye, that I cannot forbear believing their origin to be similar, at least, that some circumstances in the formation of each are the same. You will say, with reason, that the difference, notwithstanding the apparent similitude, is in reality very wide; that these clays before they can be converted into jaspers, require to be consolidated and impregnated with a considerable proportion of siliceous earth. It is something, however, to have detected nature in the act of forming, in any substance, the veins and figures common to marbles and jaspers. What still remains of the process, after thus much of it has been traced, may not long continue unknown; and in Iceland, probably sooner than elsewhere, will be discovered beds of clay, like this, hardening into stone, either by the effect of subterraneous heat or pressure promoting an adhesion of the particles, or by some insinuation of matter (perhaps siliceous) into the pores of the mass.

There is another fountain in the valley not much inferior in beauty to that which I have described. It breaks out from under one of the mounds close to the river. Its eruptions are, I think, in some respects, more beautiful than those of the former. They rise nearly to the same heights, and the quantity of water thrown up at one time is greater, and not so much scattered into spray. The jets continue seldom longer than a minute, and the intervals between them are from five to six minutes. They are forced to bend forwards from the well, by the shelving of the bank, or probably their height would be very considerable; for they appear to be thrown up with great force. We never dared approach near enough to look deep into the well; but we could perceive the water boiling near the surface from time to time, with much violence. The ground in front of it, was covered with a white incrustation, of a more beautiful appearance than the deposition near any other spring in this place. By a trial of it with acids, it seemed almost entirely calcareous.

I have now described to you the two most remarkable fountains in the valley of Rykum, the only two which throw up water to a considerable height with any regularity. There are some from whence, in the course of every hour or half hour, beautiful jets burst out unexpectedly; but their eruptions continue only a few

seconds, and between them the water boils in the same manner as in the other basons.

Towards the upper end of the valley, there was a very curious hole, which attracted much of our attention. It seemed to have served at some former period as the well of a fountain, but was of of an irregular form, and from four to five feet in diameter. It was divided into different hollows or cavities at the depth of a few feet, into which we could not see a great way, on account of their direction. A quantity of steam issued from these recesses, which prevented us from examining them very closely. We were stunned while standing near this cavern, and in some measure alarmed, by an amazing loud and continued noise which came from the bottom. It was as loud as the blast of air forced into the furnace from the four great cylinders at the Carron iron-works.

We could discover no water in any of the cavities; but we found near the place many beautiful petrifactions of leaves and mosses. They were formed with extreme delicacy, but were brittle, and would not bear much handling; their substance seemed chiefly argillaceous.

We perceived smoke issuing from the ground in many places in the higher parts of the valley, much further than we extended our walks. I am sorry to say we left many things in this wonderful country unexamined; but we were checked in our journey by many circumstances, which allowed us neither the leisure nor the opportunity for exploring every part of it as we could have wished. The substances deposited near the different springs seemed to me, in general, a mixture of calcareous and argillaceous earths; but near one spring, not far from our tents, there seemed to be a slight deposition of siliceous matter. To the eye it resembled calcedony; but with its transparencey, it had not the same hardness, and, if pressed, would break to pieces. The water you have analysed came from this spring, and we were obliged to take some care in filling the bottles; for though gradually heated, they would break when the water was poured into them, if it had not been previously exposed to the air for some minutes in an open vessel.

The water of this spring boiled, as in most of the others, in a cauldron four or five feet broad. I do not recollect to have seen any of it ever thrown up above a foot, and some meat we dressed in it tasted very strongly of sulphur.

Mr. Baine, by a measurement of the depth, the breadth and the velocity of the stream flowing from the little Geyser, found the quantity of water thrown up every minute by it to be 590.64 wine gallons, or 78.96 cubic feet. Mr. Wright and myself followed the stream, to observe how far any matter continued to be deposited by the water. We found some little still deposited where it joined the river, a quarter of a mile at least from its source. At that place it retained the heat of 33 degrees by Fahrenheit's thermometer.

The vegetation on the banks of the stream, and in the pleasant meadows through which it flows, is exceedingly luxuriant. The farmer and his people were at this time employed in cutting the hay in them, which, though not high, was thick, and remarkably sweet. The plants which Mr. Wright found in the greatest perfection, were the sedum acre *, the veronica becabunga †, the polygonum viviparum ‡, and the comarum palustre ‖.

A little above, where the current from the little Geyzer falls into the river, part of the lava, which has descended from the upper into the lower plain, has assumed close to its banks, for the space of some yards, a regular columnar shape. The pillars are short, and have five or six sides. I cannot be very exact in my account of them, as they were on the opposite side of the river. I should suppose they were nearly a foot and a half in diameter. Some were horizontal, and others vertical. We observed the same appearance in many of the tracts of lava we traversed on our journey, and, in one or two instances, in those which had flowed from the sides of Mount Hecla, though the pillars there were less perfectly defined.

So many streams of hot water fall into the river, that it receives from thence a very perceptible degree of heat. The thermometer, immersed in it above where it is joined by the waters of the little Geyzer, rose to 67 degrees, while in the open air it stood at 60. The breadth of the river in the same place is forty feet; its mean depth two feet and an half, and its course is rather rapid. Several kinds of fish are found in it; in particular, numbers of very fine salmon.

The village of Rykum or Ryka, called either indiscriminately from *Ryk*, an Icelandic word, signifying smoke, is situated in the middle of the valley, and, by an observation made by Mr. Baine,

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* Pepper-stone crop.

† Brook lime.

‡ Snake weed.

‖ Purple marsquefoil.

is in latitude 64° 4′ 38″ N. about twenty miles from Rykiavick, and eight or ten from Oreback, a small harbour on the southern coast of the island. The village consists of the farmer's house, and the houses of his servants or dependents, and a small church. All the adjacent lands belong to him, and he keeps a considerable number of sheep and cattle, and some few horses. These constitute his riches; and he purchases at Rykiavick, with skins, wool and butter, whatever he requires, of which the chief article is fish, for his winter's provision.

I have now related to you every circumstance that has occurred to me worth mentioning concerning this interesting valley. I have regretted much, however, my inability to give you a more accurate account of some parts of it; in particular, of the many springs which break out near the hills to the north, and of the rocks above the field where we placed our tents, which deserved more attention than I gave to them. But we remained in this valley a short time only, and the weather, during our continuance there, was very unfavourable. I shall here close this letter, and reserve for another (which you may very soon expect) the account I have yet to send you of the Great Geyzer and the springs near Haukadal. I am, Dear Sir, with great esteem, your most obedient servant,

JOHN THO. STANLEY.

2. *Geysers, or Haukadal Springs.*

PART of my promise has been accomplished in a former letter, in which I gave you the fullest account I could of the springs of boiling water that rise in the valley of Rykum. It now remains for me to send you a description of those we visited in the neighbourhood of Haukadal.

These last are the most remarkable in the island, and the eruptions of water from some of them so astonishing, that I doubt whether any adequate idea of their effect can be given by description. Abler pens than mine might fail probably in attempting to do justice to such wonderful phenomena. The objects, however, are so highly interesting in themselves, that even the simplest narrative that can be given of them will be read with more than ordinary attention.

They are situated about six and thirty miles from Mount Heckla, and about twelve miles, in a north east direction, from the village

of Skalholt *. The road from thence to the springs is oyer a flat country, which, although marshy in several places, is not unpleasant to the eye, and abounds in excellent pasturage.

The steam ascending from the principal springs during their eruptions, may be seen from a considerable distance. When the air is still, it rises perpendicularly like a column to a great height; then spreads itself into clouds, which roll in successive masses over each other, untill they are lost in the atmosphere. We perceived one of these columns, when distant sixteen miles at least, in a direct line from Haukadal.

The springs mostly rise in a plain, between a river that winds through it, and the base of a range of low hills. Many however break out from the sides of the hills, and some very near their summits. They are all contained, to the number of one hundred or more, within a circle of two miles.

The most remarkable spring rises nearly in the midst of the other springs, close to the hills. It is called Geyzer †; the name probably in the old Scandinavian language for a fountain, from the verb *geysa*, sygnifying *to gush*, or *to rush forth*. The next most remarkable spring rises at a distance of one hundred and forty yards from it, on the same line, at the foot of the hills. We called it the new Geyzer, on account of its having but lately played so violently as at present.

There are others of consequence in the place, but none that approach to these in magnificence, or that, when compared with them, deserve much description. The generality of the springs are in every respect similar to those near Rykum; boiling in cauldrons of three or four feet diameter, and some of them throwing their

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* Skalholt consists of the Cathedral, a large building of wood, and of a very few houses belonging to the Bishop and his dependants. The Bishops of the southern division of Iceland have always resided there; but in future their residence will be at Rykiavick, a town now building on the south-west coast of the island. The present Bishop, however, the worthy and learned Mr Finsen, has obtained the permission of continuing his residence at Skalholt during the remainder of his life.

† Three or four only of the principal springs in Iceland are distinguished by the name of Geyzer, and of all the springs near Haukadal the greatest is alone called Geyzer, or Great Geyzer.

water from time to time by sudden jets into the air. Many springs in this place, as in the other, boil through strata of coloured clay, by which they were rendered turbid. Here, however, the red clays were brighter, and in a greater proportion to the clays of other colours. Here also, as in the valley of Rykum, are many small springs, which throw out sulphureous vapour, and near which the ground, and the channel of the water, are covered and lined with a thin coat of sulphur.

The farm of Haukadal, and the church of the parish, stand near to each other, about three quarters of a mile beyond the great spring. The house is one of the best built in Iceland. It occupies a large space of ground, and consists of several divisions, to each of which there is an entrance from without. Some of these are used as barns and stables for the cattle, and others as work-shops*. The dwelling part of this house was small but comfortable. There was a parlour with glass windows, a kitchen, and separate bed-chambers for the family. The building was partly of stone, partly of wood, and covered with sods, under which the bark of birch trees on boards are generally placed, as a greater security against rain.

We were obliged to the mistress of this farm, who was a rich widow, for a very hospitable reception, although at first she seemed to consider us rather as unwelcome visitors, and left us, though we had requested admittance into her house, as we were drenched with rain, and our tents and baggage not yet arrived, to take up our lodging in the church. We had not been long there, however, before she invited us to her house, and by her kindness made ample amends for her former inattention. She put us in possession of her best room, and set before us plenty of good cream, some wheat cakes, sugar, and a kind of tea made of the leaves of the *dryas octopetala* †.

I mention these circumstances of our reception at Haukadal, as

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* As the division of labour is yet very imperfect in Iceland, the farmer is under the necessity, either of exercising himself the several trades required in the formation of the instruments of agriculture, or of maintaining such servants as are capable to supply them.

† Called in English the Mountain Avens. We found this plant growing very luxuriantly, and in great abundance, on every part of Iceland that we visited.

characteristic of the manners of the Icelanders. Several times during my stay in the country, I experienced this succession of civility to coldness. The Icelanders are naturally good, but not easily roused to feeling. When once their constitutional indifference was overcome we usually found them desirous of pleasing, and zealous to do us service.

As the house was not sufficiently large to contain the whole of our party, we were under the necessity of returning again to the church as soon as our baggage arrived. Here we passed the first and second nights of our stay, in the neighbourhood of the springs. On the third day, we left Haukadal, to fix ourselves in some station nearer to them, from which we could watch their eruptions with more convenience.

The view from near the church was very beautiful. It extended toward the south along the plain into an open country. On the other sides, it was bounded by hills, which had not the barren and rugged appearance that deform almost every scene in this division of the island. It was, however, still finer from some of the eminences near the springs. The plain and the surrounding mountains, seen from a height, appeared to more advantage; and the eruptions from the great wells breaking from time to time the general stillness that prevailed, were much more distinct. The course of the river, winding under the eye, could be traced with greater accuracy. It flows through the plain into an open country, where, being increased by the waters of numerous streams and rivulets, it bends to the westward, and near Skalholt falls into a considerable river, the Huit-aa.

The pleasant and fertile pastures near its banks were enlivened by numerous herds of cattle and sheep, the united riches of three or four farmers in the neighbourhood of Haukadal. The mowers also at work in the different fields surrounding each house, gave at this season additional beauty to the prospect. High hills to the westward were separated from the eminencies immediately above the springs by a narrow valley. They were partly clothed with bushes of birch, which, although in no place above five foot high, were gratifying to the sight, which so seldom in Iceland can rest on any appearance even of underwood. Above these, some vegetation still continued to cover the sides of the hills, and Mr. Wright found

MODE OF TRAVELLING OVER THE SNOW IN ICELAND.

a variety of plants* near their summits, which were certainly, in some places, not less than sixteen hundred feet above the plain.

To the eastward, the plain, several miles in breadth, was bounded by a long range of blue mountains, extending considerably to the south. Beyond these, the triple summit of Heckla may be seen from the western hills; but I could not distinguish it from the plain, or even from the heights whence the view of the surrounding country was taken which I am now describing.

To the north behind Haukadal, there were many high mountains, but at a great distance, and of which the most distant were covered with snow. They formed part of a dreary assemblage of *Jokuls* or ice-mountains, which occupy a considerable extent of the interior country. Their forms were mostly conical; and from their general resemblance to other mountains in the island, from which streams of lava have been emitted, I think it probable they were once volcanos. They are not so connected as to form a continued range or chain of hills. Each stands insulated; and therefore the snows which have for ages rested on their sides, are no more accumulated in valleys and converted into lakes of ice and glaciers, as amidst the Alps of Switzerland and Savoy.

A view so different from the general features of the country, impressed us with the most agreeable sensations. Hitherto we could but compare one scene of dreariness with another; and although the view before us was destitute of trees, yet the verdure and pleasant distribution of hills and plain, in some measure compensated for this deficiency.

I now return to the account of the springs, which I have already observed break out in different places from the sides of a hill, and the space enclosed between its base and the windings of a river. The soil through which they rise is a mixture of crumbled materials, washed by degrees from the higher parts of the hill. In some places these have been reduced into a clay or earth; in others, they still remain loose and broken fragments of the rocks from whence they have fallen, or a dust produced by their friction against each other.

* Amongst others, he found the *salix herbacea* (test willow) the *cerastium tomentosum* (woolly mouse ear chickweed), the *rumex digynus* (round leaved mountain sorrel), and the *koenigia*, (a plant peculiar to Iceland), growing in great abundance, though generally in low and marshy grounds.

Wherever the ground is penetrated by the stream of the springs, these fragments are soon decomposed, or changed into coloured clays. In other places the surface of the ground is covered with incrustations deposited by the springs, or with a luxuriant vegetation of grass, or dwarf bushes of willow and birch, and the *empetrum nigrum* *, the berries of which were at this time ripe and in great abundance.

Above the great spring, the hill terminates in a double pointed rock, which Mr. Baine found by measurement to be 310 feet higher than the course of the river; the rock is split very strangely into lamina, and at first sight has much the appearance of a schistus or thick slate. It consists, however, of a grey coloured stone of a very close grain, the separate pieces of which, although divided as they lay, do not break in the hand in any particular direction. I should suppose the substance of the rock to be chiefly argillaceous, and that like every other stone in the island, it has suffered some change by the action of fire. I do not mean to call it lava, as it bears no mark of having been once in a melted state, whatever baking or induration it may have sustained in the neighbourhood of subterraneous heat. It contains no heterogeneous matter, or cavities, in which agates, or zeolites, or vitrified substances of any kind, could have been formed.

All these rocks that have been either altered or created by fire, seem much more liable to decay and decomposition than any others I have ever seen. Mounds, similar to those in the valley of Rykum have been formed by the ruins of the hill half way up its ascent between the Geyzer and the pointed rock. Springs boil in many places through these mounds, and near to one of them I observed that the coloured clay felt much more soapy than any I had tried before. This quality probably was owing to a greater proportion of the earth of magnesia in its composition, as in other respects it agreed perfectly with the rest.

My attention, during the four days I remained in this place, was so much engaged with the beauties and remarkable circumstances of the two principle springs, that I cannot (were I so inclined) give you

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* The crow berry. This is almost the only fruit we met with in Iceland, Mr. Wright found a few strawberries. Neither gooseberries nor currants will come to perfection by any management whatever.

a minute account of those which, next to them, were deserving of notice. The springs in general resemble those at Rykum; but there are five or six which have their peculiarities, and throw up their waters with violence to a considerable height. Their basons are of irregular forms, four, five or six feet in diameter, and from some of them the water rushes out in all directions, from others obliquely. The eruptions are never of long duration, and the intervals are from 15 to 30 minutes. The periods of both were exceedingly variable. One of the most remarkable of these springs threw out a great quantity of water, and from its continual noise we named it the Roaring Geyzer. The eruptions of this fountain were incessant. The water darted out with fury every four or five minutes, and covered a great space of ground with the matter it deposited. The jets were from thirty to forty feet in height. They were shivered into the finest particles of spray, and surrounded by great clouds of steam. The situation of this spring was eighty yards distant from the Geyzer, on the rise of the hill.

I shall now, Sir, attempt some description of this celebrated fountain, distinguished by the appellation of Geyzer alone, from the pre-eminence it holds over all the natural phenomena of this kind in Iceland.

By a gradual deposition of the substances dissolved in its water for a long succession of years, perhaps for ages, a mound of considerable height has been formed, from the centre of which the Geyzer issues. It rises through a perpendicular and cylindrical pipe, or shaft, seventy feet in depth, and eight feet and a half in diameter, which opens into a bason or funnel, measuring fifty-nine feet from one edge of it to the other. The bason is circular, and the sides of it, as well as those of the pipe, are polished quite smooth by the continual friction of the water, and they are both formed with such mathematical truth, as to appear constructed by art. The declivity of the mound begins immediately from the borders of the bason. The incrustations are in some places worn smooth by the overflowing of the water; in most, however, they rise in numberless little tufts, which bear a resemblance to the heads of cauliflowers, except that they are rather more prominent, and are covered, by the falling of the finer particles of spray, with a crystalline efflorescence so delicate as scarcely to bear the slightest touch. Unmolested, the efflorescence gradually hardens, and

although it loses its first delicacy, it still remains exceedingly beautiful.

These incrustations are of a light brown colour, and extend a great way in various directions, from the borders of the bason. To the northward, they reach to a distance of 82 feet; to the east of 86; to the south of 118; and of 124 to the west. They are very hard, and do not appear, in any part, decaying or mouldering into soil *.

When our guides first led us to the Geyzer, the bason was filled to within a few feet of its edge. The water was transparent as crystal; a slight steam only arose from it, and the surface was ruffled but by a few bubbles, which now and then came from the bottom of the pipe. We waited with anxiety for several minutes, expecting at every instant some interruption to this tranquillity. On a sudden, another spring, immediately in front of the place on which we were standing, darted its waters above an hundred feet into the air with the velocity of an arrow, and the jets succeeding this first eruption were still higher. This was the spring already mentioned under the name of the New Geyzer.

While gazing in silence and wonder at this unexpected and beautiful display, we were alarmed by a sudden shock of theground under our feet, accompanied with a hollow noise, uot unlike the distant firing of cannon. Another shock soon followed, and we observed the water in the bason to be much agitated. The Icelanders hastily laid hold of us, and forced us to retreat some yards. The water in the mean time boiled violently, and heaved as if some expansive power were labouring beneath its weight, and some of it was thrown up a few feet above the bason. Again there were two or three shocks of the ground, and a repetition of the same noise. In an instant, the surrounding atmosphere was filled with volumes of

* The substance of these incrustations has been analysed by Professor Bergman, and he gives a long and particular account of it, in a letter to the Archbishop of Upsal, published with the Archbishop's Letters on Iceland. He says, "The strongest acids, the fluor acid not excepted, are not sufficient with a "boiling heat to dissolve this substance: It isdissolved very little (if at all) by "the blow-pipe with the fusible salt of urine, a little more with borax, and "makes a strong effervescence with sal sodæ. These effects are peculiar only "to a siliceous earth or flint. There cannot remain therefore a doubt concerning the nature of this crustated stone."

steam rolling over each other as they ascended, in a manner inexpressibly beautiful, and through which, columns of water, shivering into foam, darted in rapid succession to heights which, at the time, we were little qualified to estimate. Indeed, the novelty and splendour of such a scene had affected our imaginations so forcibly, that we believed the extreme height of the jet to be much greater than it was afterwards determined to be. In a subsequent eruption, Mr. Baine ascertained, by means of a quadrant, the greatest elevation to which the jets of water were thrown, to be 96 feet.

Much of the water began to descend again at different heights and was again projected by other columns, which met it as they arose. At last, having filled the bason, it rolled in great waves over numberless rills, made its way down the sides of the mound. Much was lost in vapour also, and still more fell to the ground in heavy showers of spray. The intervals at which the several jets succeeded each other, were too short for the eye to distinguish them. As they rose out of the bason, they reflected by their density, the purest and most brilliant blue. In certain shades, the colour was green like that of the sea; but in their further ascent, all distinction of colour was lost, and the jets, broken into a thousand parts appeared white as snow. Several of them were forced upwards perpendicularly; but many, receiving a slight inclination as they burst from the bason, were projected in beautiful curves, and the spray which fell from them, caught by a succeeding jet, was hurried away still higher than it had been perhaps before.

The jets were made with inconceivable velocity, and those which escaped uninterrupted terminated in sharp points, and lost themselves in the air. The eruption, changing its form at every instant, and blending variously with the clouds of steam that surrounded it, continued for ten or twelve minutes; the water then subsided through the pipe, and disappeared.

The eruptions of the Geyzer succeed each other with some degree of regularity, but they are not equally violent, or of equal duration. Some lasted scarcely eight or ten, while others continued, with unabated violence, fifteen or eighteen minutes. Between the great eruptions, while the pipe and bason were filling, the water burst several times into the air to a considerable height. These partial jets, however, seldom exceeded a minute, and sometimes not a few seconds, in duration.

After the eruption of it had been violent, the water sank into subterraneous caverns, and left the pipe quite empty. If the eruption had been moderate the subsidence of the water was proportionably less. The first time the pipe was perfectly emptied, we sounded its depth, and found the bottom very rough and irregular. The pipe remains but a short time empty. After a few seconds, the water rushes into it again with a bubbling noise, and during the time that it is rising in the pipe, it is frequently darted suddenly into the air to different heights, sometimes to two or three, sometimes sixty feet above the sides of the bason. By a surprise of this kind, while we were engaged measuring the diameter of the well we had nearly been scalded; and although we were able to withdraw ourselves from the great body of water as it ascended, yet we remained exposed to the falling spray, which fortunately was so much cooled in the air as to do us no mischief.

Of these jets we counted twenty in an hour and an half, during which the waters had filled the pipe and in part the bason. It then seemed oftentimes agitated, and boiled with great violence. The jets were more beautiful, and continued longer, as the quantity of water in the bason increased. The resistance being greater, their force was in some degree broken, and their form, more divided, produced a greater display of foam and vapour.

While the pipe was filling, we threw into it several stones of considerable weight, which, whenever the water burst forth with any violence, were projected much higher than itself. These stones in falling were met by other columns of water, and amidst these they rose and fell repeatedly They were easily distinguished in the white foam, and contributed much to the novelty and beauty of this extraordinary phenomenon.

When the bason was nearly full, these occasional eruptions were generally announced by shocks of the ground, similar to those preceding the great eruptions. Immediately after the shocks, the whole body of water heaved exceedingly; a violent ebullition then took place, and large waves spread themselves in circles from the centre, through which the column forced its way.

When the water had been quiet in the bason for some time, the thermometer placed in it stood at 180° only, but immediately after an eruption it rose to 200°. We boiled a piece of salmon in it,

which was exceedingly well tasted. Our cookery at Rykum had not been quite so successful.

The water thrown out from the Geyzer is joined at the bottom of the mound by that which flows from the spring called the roaring Geyzer, formerly described. The stream produced by their united waters flows three or four hundred paces before it falls into the river, where its temperature is reduced to 72°. Even at this place it deposited much of the substances it contained; but during the whole of its course, the plants growing on its banks were covered with beautiful incrustations. Some of these we wished to preserve, but from their extreme delicacy they fell into pieces on every attempt to remove them.

The situation of the new Geyzer * is in the same line from the foot of the hill with the great Geyzer. Its pipe is formed with equal regularity, and is six feet in diameter, and forty-six feet ten inches in depth. It does not open into a bason, but it is nearly surrounded by a rim or wall two feet high, After each eruption, the pipe is emptied, and the water returns gradually into it as into that of the old Geyzer. During three hours nearly that the pipe is filling, the partial eruptions happen seldom, and do not rise very high; but the water boils the whole time, and often with great violence. The temperature of the waters after one of these eruptions, was constantly found to be 212°. Few incrustations are formed round this spring, excepting in the channel where the water flows from it.

The great eruption is not preceded by any noise, like that of the great Geyzer. The water boils suddenly, or is heaved over the

* Before the month of June 1789, the year I visited Iceland, this spring had not played with any degree of violence, at least for a considerable time. (Indeed the formation of the pipe will not allow us to suppose, that its eruptions had at no former period been violent.) But in the month of June, this quarter of Iceland had suffered some very severe shocks of an earthquake; and it is not unlikely, that many of the cavities communicating with the bottom of the pipe had been then enlarged, and new sources of water opened into them. The difference between the eruptions of this fountain, and those of the great Geyzer, may be accounted for from the circumstance of there being no bason over the pipe of the first, in which any water can be contained to interrupt the column as it rises. I should here state, that we could not discover any correspondence between the eruptions of the different springs.

sides of the pipe; then subsiding a little, it bursts into the air with inconceivable violence. The column of water remains entire, untill it reaches its extreme height, where it is shivered into the finest particles. Its direction was perpendicular, and greatest elevation 132 feet. Like the eruption of the old Geyzer, this consisted of several jets, succeeding each other with great rapidity. Whatever we threw into the well was hurled into the air with such swiftness that the eye could scarcely discern it*, and the division of the water at the extremity of the column was so minute, that the showers of spray which fell were cold. Towards the end of an eruption, when more steam than water rushed from the pipe, I ventured to hold my hand near the edge of the column, in the way of some divided particles of water, and found them tepid only. You may probably think this a rash experiment, and certainly it was so. But we had made our observations on the uniform direction of the column, and confided our safety in it. Once or twice, however, we had reason to think ourselves more fortunate in escaping, than prudent in avoiding, the danger which attended a too near approach to these eruptions of boiling water. During ten or fifteen minutes, the water continued to be thrown upwards with undiminished impetuosity. At the end of that period, the quantity became less, and at length, ceasing entirely, steam alone ascended. In one instance, the eruption continued thirty minutes. It seldom however exceeded twenty minutes, and sometimes was completed in fifteen minutes. The force with which the steam rises abates as the water sinks in the pipe, and when this is exhausted, that soon disappears.

I have now given you such a description of these celebrated fountains as was in my power. I hope that it will afford you some satisfaction, and I could wish that it might serve as an inducement to some curious inquirer into the history of nature to visit them, who shall have all the knowledge requisite for making such observations as are yet to be desired concerning them. I cannot flatter myself, that the description I have attempted of their eruptions will impress you with a just idea of their beauty. Sources of comparison are wanting, by which the portraiture of such extraordinary

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* Mr. Baine measured the height to which a stone was thrown up by one of these jets, and found it 129 feet. Some others rose considerably higher.

scenes can be assisted. Nature no where offers objects bearing a resemblance to them; and art, even in constructing the water-works of Versailles, has produced nothing that can at all illustrate the magnificent appearances of the Geyzer. All then that I hope for is, to have said so much as may enable you to complete in your imagination, the picture which I have only sketched. Imagination alone can supply the noise and motion which accompany such large bodies of water bursting from their confinement; and must be left to paint what I have not been able to describe, the brilliancy of colouring, the purity of the spray, the quick change of effect, and the thousand varieties of form into which the clouds of steam, filling the atmosphere on every side, are rolled incessantly.

I have avoided entering into any theory of the cause of these phenomena, that you may not suppose the account I give you has been biassed by a favourite hypothesis: I have given you an accurate state of facts, and I leave to you the explanation of them. There cannot, however, be two opinions concerning the immediate cause which forces the water upwards. It is obviously the elasticity of steam endeavouring to free itself. In addition to this, the form of the cylinder through which the water rises, gives it that projectile force which carries it so high. Beyond this, it would not become me to hazard any opinion.

Of the antiquity of these springs I can say nothing further than that they are mentioned as throwing up their waters to a great height by Saxo Grammaticus, in the Preface to his History of Denmark, which was written in the twelfth century; but from the general features of the country, it is likely that they have existed a great length of time. The operations of subterraneous heat seem indeed to be of great antiquity in Iceland; and the whole country probably owes its existence to the fires which burn beneath its surface. Every hill proves, at least, with what violence these fires have acted for ages; and the terrible eruption of lava which burst from the mountains of Skaptefield in 1783, show that they are as yet far from being extinguished.

[*Transactions of the Royal Society of Edinburgh, Vol.* 3.]

SECTION VI.

Alternating Hot and Cold Springs.

THERE are many tepid springs which, without any real change in their temperature, appear to the people that frequent them to be much warmer in the winter than in the summer. Of these we have already given an example in the preceding section, in describing the warm springs in the district of Troas. The apparent variation in such cases depends altogether upon the real variation in the temperature of the atmosphere: the water sinking the thermometer below the temperature of the surrounding air in summer, but raising it perhaps twenty or thirty degrees above that of the winter season.

There are other springs and fountains, however, in which there is a real difference in the temperature of the water at different seasons, as measured by the thermometer when plunged into the water itself: and while in some instances these alterations are irregular, in others they are fixed and periodical. Both these facts have been known to natural philosophers through a long series of ages; and the last is thus minutely exemplified by Lucretius in his Nature of Things, vi. 848.

> Esse apud Hammonis * fanum funs luce diurnâ
> Frigidus, et calidus nocturno tempore, fertur,
> Hunc homines funtem nimis admirantur, et acri
> Sole putant subter terras fervescere partim,
> Nox ubi terribili terram caligine texit:
> Quod nimis a verâ est longe ratione remotum.

> A fount, 'tis rumour'd, near the temple purls
> Of JOVE AMMONIAN, tepid through the night,
> And cold at noon-day; and th' astonished sage
> Stares at the fact, and deems the punctual sun
> Strikes through the world's vast centre, as the shades
> Of midnight shroud us, and with ray reverse
> Madden the well-spring: creed absurd and false.
>
> GOOD.

* We quote from Wakefield's edition.

And the philosophic poet having, thus, peremptorily spurned the common theory, immediately proceeds to unfold his own, which offers a striking consonance to several of the chemical opinions of the present day. He supposes that the elementary principles of caloric are driven together and concentrated by the contraction of the sides of the fountain that takes place upon the return of the evening cold, in the same manner as we now suppose them to be driven together and concentrated by the contraction that takes place in the percussion of solid bodies; in consequence of which the water, or whatever other substance may hereby be exposed to such concentrated action, must necessarily become proportionably heated. His words are as follows, which we shall interpret in the language of the translator and annotator from whom we have already quoted.

Quæ ratio est igitur? nimirum, terra magis quod
Rara tenet circum funtem, quam cætera tellus;
Multaque sunt ignis prope semina corpus aquaï.
Hoc, ubi roriferis terram nox obruit umbris,
Ex templo subtus frigescit terra, coitque;
Hac ratione fit, ut, tamquam conpressa manu sit,
Exprimat in funtem, quæ semina quomque habet ignis;
Quæ calidum faciunt laticis tactum, atque vaporem.
Inde, ubi sol radiis terram dimovit abortis,
Et rarefecit, calido miscente vapore;
Rursus in antiquas redeunt primordia sedes
Ignis, et in terram cedit calor omnis aquaï:
Frigidus hanc ob rem fit funs in luce diurnâ.

Dost thou the cause demand, then?—clearly hence:
That round the fountain earth more spongy spreads,
And seeds of fire throng ampler: whence, when night
Pours o'er the world his dew-distilling shades,
The chill'd, contracting soil here strains abrupt
As though comprest by fingers, tow'rds the fount
Suck seeds profusely, and the bubbling wave
Proves to the touch, the taste, more tepid proves.
But when, revers'd, the sun with new-born beam
Earth rarefies and quickens, back profound
Fly the young fire-seeds to their native haunts,

The fount forsaking: whence the sparkling tide
Tastes in the day more frigid than at night.

Upon this striking passage Mr. GOOD, from whose translation we have copied, has the following note, which we also copy, as being peculiarly apposite to the present occasion.

"Of the existence of this curious fountain there can be no doubt. It is particularly described by Quintus Curtius, iv. 7. Pliny, ii. 103; and Pomponius Mela, i. 8. It is also referred to by Silius Italicus, iii. 669, and by Ovid in the following distich:

Medio tua, corniger Hammon!
Unda die gelida est: ortuque, obituque, calescit.

Thy stream, O horn-crown'd Ammon! in the midst
Chills us at noon, but warms at morn and eve.

"The heat of this fountain was unquestionably supplied from subterranean inflammable substances in a state of combustion. Its alteration of cold in the day-time may have been produced, and especially in the summer season, by evaporation from the groves that surrounded it; or by the subsidence of a regular hot tide, like the pool of Bethesda, described by St. John, v. 2—4. which seems to have been possessed of powers in many respects similar. The Roman fountain was, probably, like the Jewish, a *hot spring with a tide, recurring once in every twenty-four hours; with this only difference, that the tide of the latter returned about noon, and that of the former at sun-set or midnight. Our own country has a great number of these extraordinary springs; but they are in general so well supplied with subterranean heat as to suffer no intermission whatever.* The Weeden well in the celebrated peak of Derbyshire, has an undoubted flux and reflux of its waters, but its tide is irregular, and it is not supplied with heat from below. The most extraordinary hot springs we are acquainted with are those at Geyser and Rykum, both in Iceland. Their heats return with their tides; but these tides, though irregular in their periods, recur so frequently as to prevent their waters from ever becoming cold. That of the former returns ten or twelve times in the course of the day; and such is the extreme calidity and

consequent ebullition during these recurrences, that its waters are projected in a jet-d'eau of not less than from five to ten fathoms of perpendicular height. The tides of the hot-springs at Rykum, for there are several, are renewed still more frequently; often, indeed, not less than two or three times in the course of a quarter of an hour. The very curious hot spring described by Captain Billings (*Expedition to the Northern Parts of Russia*) near the volcano of Opalsk in Kamscatka, is so incessantly supplied with subterranean heat, as to be permanently ebullient.—It is very extraordinary that the *ice* in the celebrated cavern of Grace-Dieu, is plentiful and solid during the summer, and almost wholly wasted in the winter season. M. Cadet, in a paper inserted in the Annales de Chymie, vol. xlvi. has endeavoured to account for this anomaly, by the increase of cold produced by the evaporation from the moist and massy foliage that surrounds the cavern during the summer months. He has here, perhaps, given us the real cause of the variation in the temperature of the fountain before us, but it is a cause scarcely adequate to the production of ice in summer, though it may make a warm stream colder in the day time than at night."

To this full and explicit account we shall only add the two following coincident facts. "In the midst of the river Men, south of Peterborough in Northamptonshire," says the humourous and enterprising Isaac Walton, "is a deep gulph called Medeswell, so cold that *in summer* no swimmer is able to endure it, yet it is not frozen in the winter." And Mr. Wales, in his Journal of a thirteen month's residence on the north-west coast of Hudson's Bay, which we shall more particularly advert to in a subsequent chapter, tells us, that when he was staying at one of the hunter's tents for about a week in the month of December, he was told that there was a spring very near them, which was not yet frozen over, though the sea was frozen up as far as could be seen, and the ice in the river was four or five feet thick. He went to see it: but that morning the frost had been so intense, that it was frozen over about an inch thick. He broke the ice, and, to his surprize, found the water so shallow, that the mud was immediately raised from the bottom by the act of breaking it. The adjoining springs, that were at least six times its depth, had at this period been frozen quite dry for several weeks. We regret that Mr. Wales has given us no account of the actual temperature or the mineral principles of this singular well.

EDITOR.

SECTION VII.

Inflammable Springs, Wells, and Lakes.

1. *Introductory Remarks.*

We have already observed that the materials with which water becomes combined in a long or devious subterranean course, must be very numerous, and of very different qualities: for as it is the most general solvent in nature, it is capable of dissolving or of holding in suspension, a part of most of the substances through which it travels or which it accidentally encounters, whether earthy, oleaginous, or gasseous.

It hence, as we have already seen, frequently becomes united with large quantities of caloric, and produces tepid or hot springs; sometimes with pure air or other gasses, and produces bubbling springs, or those which to the eye have the appearance of boiling, but to the touch or to the thermometer are found cold; and sometimes with highly inflammable or combustible substances, and are hence capable of firing or supporting flame.

Of this last kind we have various instances both in wells or fountains, and in lakes; and though the instances are not, perhaps, very numerous, they have been known from a very early era, and when chemically examined, have been chiefly found to consist of hydrogen gass, or some bituminous preparation, as naphtha, asphalt, rock oil, or petroleum.

One of the earliest of these inflammable fountains that occur to us in an unquestionable character is that of Dodona, situated near the temple of Jupiter, and which, as has been already hinted at by Mr. Gough in an article we have just quoted from him *, seems also to have been a periodical spring. One of the first and best authenticated accounts we have of this burning fountain is to be met with in Lucretius, to whose comprehensive research as a natural philosopher, we have already had frequent occasions of expressing our obligations. It occurs in lib. vi. 879, of his Nature of Things, as follows:

* See the present Chapter, Sect. iv. art. 5. Giggleswick Well.

Frigidus est etiam funs, supra quem sita sæpe
Stuppa jacit flammam, concepto protinus igni;
Tedaque consimili ratione, adcensa per undas,
Conlucet, quoquomque natans inpellitur auris:

A fount there is, too, which though cold itself,
With instant flare the casual flax inflames
Thrown o'er its surface; and the buoyant torch
Kindles alike immediate, o'er its pool
Steering the course th' etherial breeze propels.

GOOD.

Upon this subject we must again have recourse to the learned translator's explanation and exemplification of this curious phænomenon, which he gives us in the following note subjoined to the translation we have now copied.

"This is perhaps a more extraordinary phænomenon than that of hot springs. The account, however, is confirmed by Pliny, who adds, that it was situated near the temple erected to Jupiter at Dodona, ii. 103. 'In Dodone Jovis autem fons, cum sit gelidus, et immersas faces extinguat; si extincte admoveantur. accendit.' But this is not the only fountain of this nature of which Pliny makes mention: for in lib. xxxi, 2, he enumerates two more, the one in India, denominated Lycos; and the other at Ecbatana, which is in like manner described by Solinus. Such may have existed for any thing we can affirm to the contrary, and our author's reasoning upon the nature of their operations is at least consistent and ingenious. Even in modern chemistry the approximation of different substances that are highly charged with latent or elementary fire, the *fire-seeds* of Lucretius, although sensibly cold to the touch prior to their contact, will occasionally produce the effect here delineated, and burst forth into the most surprising and instantaneous blaze. But this phænomenon is more frequently produced by an admixture of vegetable essential oils with highly concentrated mineral acids, and especially those of nitre and sulphur, than by the union of any other substances.

"The springs here spoken of consisted, in all probability, of pure liquid bitumen; or if not, of springs on the surface of which bitumen floated in great quantities. Such are by no means unfre-

quent both in our own country and abroad; the most remarkable, perhaps, among ourselves, is that of Pitchford, in Shropshire, where the bituminous fluid bubbles forth from the earth like a fountain. In Italy they are more common still, and very general in the isle of Barbadoes. But the most extraordinary bituminous springs, of which we have any account, are in the Birman empire. In the province of Arracon Major Symes met with a considerable cluster of them, the depths of whose wells was about thirty-seven fathoms; and the column of oil contained in them generally as high as the waist of those who descended for the purpose of collecting it. The Lycos of Pliny, which, as just observed, he places in India, was probably one of these very fountains. A lighted torch or bundle of lighted tow, applied to any of these springs, will immediately set the whole surface in a blaze; and, perhaps, if such torch or tow were to be strongly impregnated with highly concentrated nitric, or sulphuric acid, they would produce the same effect, even without being lighted. The essential oil that most certainly inflames when suddenly blended with these mineral acids, is that of turpentine, an oil allied to bitumen. It is probable, therefore, that in the case to which Lucretius alludes, the torch or tow made use of was always previously impregnated, if not with nitric or sulphuric acid, with some other substance possessed of a similar inflammability. The inhabitants of the Ligurian republic have lately employed, with great advantage, the petroleum of a spring recently discovered at Amiano, for the purpose of lighting their towns and cities: the petroleum is pure; its specific gravity to that of water being as 83 to 100: to oil olive as 91 to 100. In the neighbourhood has also been lately discovered a stratum of bituminous wood, which is of equal use as a fuel. It easily inflames and gives a stronger heat than the charcoal of oak. Its cinders contain potash, oxyd of iron, lime and magnesia. See Annales de Chemie, vol. xlv.

"It is to a tree and a fountain of this description, that Camoens refers in the following verses of his Lusiad; which I quote in further confirmation that I have here rightly conjectured the kind of spring adverted to by our own poet: *Cant.* x. 135.

> "Ve naquella que o tempo tornon Ilha
> Que tambem flamas tremulas, vapora,
> A fonte que oleo mana, ed a maravilha
> Do cheiroso licor, que o tronco chora.

"'Lo, gleaming blue o'er fair Sumatra's skies,
Another mountain's trembling flames arise;
Here from the trees the gum all fragrance swells,
And softest oil in wond'rous fountain wells.

MICKLE."

So far the learned translator and commentator upon the NATURE OF THINGS*: who has travelled so widely and explained himself so fully, that it only remains for us to offer a few other singular examples, in addition to those he has so curiously selected.

EDITOR.

2. *Wigan Well, in Lancashire.*

By Thomas Shirley, Esq.

ABOUT a mile from Wigan in Lancashire is a spring, the water of which is supposed to burn like oil. It is true that when we came to the spring, and applied a lighted candle to the surface of the water, there was suddenly a large flame produced, which burned vigorously. Having taken up a dishful of water at the flaming place, and held the lighted candle to it, the flame went out. Yet I observed that the water at the burning place boiled and rose up like water in a pot upon the fire, though my hand put into it felt no warmth.

This boiling I conceived to proceed from the eruption of some bitumous or sulphurous fumes; considering this place was not above 30 or 40 yards distant from the mouth of a coal-pit there. And indeed Wigan, Ashton, and the whole country for many miles compass, is underlaid with coal. Then applying my hand to the surface of the burning place of the water, I found a strong breath like a wind bear against my hand. Upon making a dam, and hindering the recourse of fresh water to the burning place, I caused that which was already there to be drained away, and then applying the burning candle to the surface of the dry earth at the same point, where the water before burned, the fumes took fire and burned very bright and vigorous. The cone of the flame ascended a foot and a half from the surface of the earth. The basis of it was of

* See Good's Translation of Lucretius, Vol. II. p. 552.

the compass of a man's hat about the brim. I then caused a bucket full of water to be poured on the fire, by which it was presently quenched. I did not perceive the flame to be discoloured like that of sulphurous bodies, nor to have any manifest smell with it. The fumes when they broke out of the earth and pressed against my hand, were not to my best remembrance at all hot *.

Phil. Trans. Abr. 1667.

3. *Broseley Spring in Shropshire.*

By Mr. Richard Hopton.

THE famous boiling well at Broseley, near Wenlock, in the county of Salop, was discovered about June, 1711. It was first announced by a terrible noise in the night, about two nights after a remarkable day of thunder: the noise awaked several people in their beds, that lived hard by; who coming to a boggy place under a little hill, about 200 yards from the river Severn, perceived a surprising rumbling and shaking in the earth, and a little boiling up of water through the grass. They took a spade, and digging up some part of the earth, immediately the water flew up a great height, and a candle that was in their hand set it on fire. To prevent the spring being destroyed, an iron cistern is placed about it, with a cover to be locked, and a hole in the middle, through which the water may be viewed. If a lighted candle, or any thing of fire be put to this hole, the water immediately takes fire, and burns like spirit of wine, or brandy, and continues so long as the air is kept from it; but by taking up the cover of the cistern, it quickly goes out. The heat of this fire much exceeds the heat of any fire I ever saw, and seems to have more than ordinary fierceness in it †.

Phil. Trans. Abr. 1712.

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* The fumes here mentioned were inflammable air or hydrogen gas, of which the rapid ascent through the water gave it the appearance of boiling.

Phil. Trans. Abr. 1667.

This well may therefore be regarded as another instance of those we have adverted to in Section V. of the present chapter, under the name of *Bubbling Springs*, or springs that from the quantity of elastic gas with which the water is combined, have the appearance of boiling without any sensible increase of heat. EDITOR.

† The apparent boiling and ascent of the water of this spring, are still more obviously the result of hydrogen gas or inflammable air, as it is commonly called,

4. *Bituminous Fountain at Cracow, with a Notice of various other inflammable Springs.*

By Dr. Tancred Robinson.

WHEN I delivered my thoughts* concerning boiling fountains, their varieties and causes, I had not then time enough to mention the burning ones, except that not only Wigan in Lancashire, with which those burning fountains, near Grenoble in Dauphine, near Cibinium or Hermanstadt in Transylvania; near Chermay, a village in Switzerland, in the Canton of Friburgh; and that not far from Cracovia in Poland, do agree in many particulars; as in being actually cold, yet inflammable and taking fire at a distance, on the application of any light body; which the boiling springs near Peroul will not do; this ought to be understood of them in their sources, because when removed from thence, neither the waters, nor their earths will produce any such phænomena, as boiling or flaming.

It is related of the burning fountain in the palatinate of Cracow, that on evaporating the water, a dark or pitch-like substance may be extracted, which cures the most inveterate ulcers in a very short time; and that the mud itself is very powerful against rheumatic and gouty pains, palsies, scabs, &c. The inhabitants of an adjacent village, drinking much of the spring, do generally live to 100 or 150 years, which is attributed to the sanative virtue of the water †.

Phil. Trans. 1685.

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than in the preceding instance of Wigan-Well. And to the reader a little acquainted with the prodigious quantities of this material that are frequently forming in cavities below the surface of the earth, it is only necessary for him to revert to the extensive and tremendous mischief produced by it on a late occasion at Felling Colliery, as already related in chapter xxxviii. section viii. of the present work. EDITOR.

* See Section v. 1. of the present chapter.

† We have already noticed in a preceding extract from Mr. Good's Translation of Lucretius, see p. 146, a more perfect pitch or bitumen obtained from a spring at Amiano, in the Ligurian Republic, and which the inhabitants of the country have been ingenious enough to employ for the purpose of lighting their towns and cities. And the ensuing article will be found to contain a far more extensive instance of a similar secretion, and capable perhaps of being converted to still more useful purposes, and upon a much larger scale. EDITOR.

5. *Pitch Lake of the Island of Trinidad.*

By Nicholas Nugent, M.D.

BEING desirous to visit the celebrated lake of pitch previously to my departure from the Island of Trinidad, I embarked with that intention in the month of October, 1807, in a small vessel at Port Spain. After a pleasant sail of about thirty miles down the Gulf of Paria, we arrived at the point la Braye, so called by the French from its characteristic feature. It is a considerable headland, about eighty feet above the level of the sea, and perhaps two miles long and two broad. We landed on the southern side of the point, at the plantation of Mr. Vessigny: as the boat drew near the shore, I was struck with the appearance of a rocky bluff or small promontory of a reddish-brown colour, very different from the pitch which I had expected to find on the whole shore. Upon examining this spot, I found it composed of a substance corresponding to the porcelain jasper of mineralogists, generally of a red colour where it had been exposed to the weather, but of light slate-blue in the interior; it is a very hard stone with a conchoidal fracture, some degree of lustre, and is perfectly opake even at the edges; in some places, from the action of the air, it was of a reddish, or yellowish-brown, and an earthy appearance. I wished to have devoted more time to the investigation of what in the language of the Wernerian school is termed the geognostic relations of this spot, but my companions were anxious to proceed. We ascended the hill, which was entirely composed of this rock, to the plantation, where we procured a negro guide, who conducted us through a wood about three quarters of a mile. We now perceived a strong sulphureous and pitchy smell, like that of burning coal, and soon after had a view of the lake, which at first sight appeared to be an expanse of still water, frequently interrupted by clumps of dwarf trees or islets of rushes and shrubs: but on a nearer approach we found it to be in reality an extensive plain of mineral pitch, with frequent crevices and chasms filled with water. The singularity of the scene was altogether so great, that it was some time before I could recover from my surprize so as to investigate it minutely. The surface of the lake is of the colour of ashes, and at this season was not polished or smooth so as to be slippery; the hardness or consistence was such as to bear any weight; and it was not adhesive, though it partially received the

impression of the foot; it bore us without any tremulous motion whatever, and several head of cattle were browsing on it in perfect security. In the dry season, however, the surface is much more yielding, and must be in a state approaching to fluidity, as is shown by pieces of recent wood and other substances being enveloped in it. Even large branches of trees which were a foot above the level, had in some way become enveloped in the bituminous matter. The interstices or chasms are very numerous, ramifying and joining in every direction, and in the wet season, being filled with water, present the only obstacle to walking over the surface: these cavities are generally deep in proportion to their width, some being only a few inches in depth, others several feet, and many almost unfathomable: the water in them is good, and uncontaminated by the pitch; the people of the neighbourhood derive their supply from this source, and refresh themselves by bathing in it; fish are caught in it, and particularly a very good species of mullet. The arrangement of the chasms is very singular: the sides, which of course are formed of the pitch, are invariably shelving from the surface, so as nearly to meet at the bottom, but then they bulge out towards each other with a considerable degree of convexity. This may be supposed to arise from the tendency in the pitch slowly to coalesce, whenever softened by the intensity of the sun's rays. These crevices are known occasionally to close up entirely, and we saw many marks or seams from this cause. How these crevices originate it may not be so easy to explain. One of our party suggested that the whole mass of pitch might be supported by the water which made its way through accidental rents; but in the solid state it is of greater specific gravity than water, for several bits thrown into one of the pools immediately sank *. The lake (I call it so, because I think the common name appropriate enough) contains many islets covered with long grass and shrubbs, which are the haunts of birds of the most exquisite plumage, as the pools are of snipe and plover. Alligators are also said to abound here; but it was not our lot to encounter any of

* Pieces of asphaltum are, I believe, frequently found floating on the Dead Sea in Palestine; but this arises probably from the extraordinary specific gravity of the waters of that lake, which Dr. Marcet found to be 1·211. Mr. Hatchett states the specific gravity of ordinary asphaltum to vary from 1·023 to 1·165, but in two varieties of that of Trinidad it was as great as 1·336 and 1·774.

these animals. It is not easy to state precisely the extent of this great collection of pitch; the line between it and the neighbouring soil is not always well defined, and indeed it appears to form the substratum of the surrounding tract of land. We may say, however, that it is bounded on the north and west sides by the sea, on the south by the rocky eminence of porcelain jasper before mentioned, and on the east by the usual argillaceous soil of the country; the main body may perhaps be estimated at three miles in circumference; the depth cannot be ascertained, and no subjacent rock or soil can be discovered. Where the bitumen is slightly covered by soil, there are plantations of cassava, plantains and pine-apples, the last of which grow with luxuriance and attain to great perfection. There are three or four French and one English sugar estates in the immediate neighbourhood: our opinion of the soil did not, however, coincide with that of Mr. Anderson, who in the account he gave some years years ago thought it very fertile. It is worthy of remark, that the main body of the pitch, which may properly be called the lake, is situated higher than the adjoining land, and that you descend by a gentle slope to the sea, where the pitch is much contaminated by the sand of the beach. During the dry season, as I have before remarked, this pitch is much softened, so that different bodies have been known slowly to sink into it: if a quantity be cut out, the cavity left will be shortly filled up; and I have heard it related, that when the Spaniards undertook formerly to prepare the pitch for œconomical purposes, and had imprudently erected their cauldrons on the very lake, they completely sank in the course of a night, so as to defeat their intentions. Numberless proofs are given of its being at times in this softened state: the negro houses of the vicinage, for instance, built by driving posts in the earth, frequently are twisted or sunk on one side. In many places it seems to have actually overflown like lava, and presents the wrinkled appearance which a sluggish substance would exhibit in motion.

This substance is generally thought to be the asphaltum of naturalists: in different spots, however, it presents different appearances. In some parts it is black, with a splintery conchoidal fracture, of considerable specific gravity, with little or no lustre, resembling particular kinds of coal, and so hard as to require a severe blow of the hammer to detach or break it; in other parts it is so much softer, as to allow one to cut out a piece in any form with a spade

or hatchet, and in the interior is vesicular and oily: this is the character of by far the greater portion of the whole mass; in one place it bubbles up in a perfectly fluid state, so that you may take it up in a cup; and I am informed that in one of the neighbouring plantations there is a spot where it is of a bright colour, shining, transparent and brittle, like bottle-glass or resin. The odour in all these instances is strong, and like that of a combination of pitch and sulphur. No sulphur, however, is any where to be perceived; but from the strong exhalation of that substance and the affinity which is known to exist between the fluid bitumens and it, much is, no doubt, contained in a state of combination: a bit of the pitch held in the candle melts like sealing-wax and burns with a light flame, which is extinguished whenever it is removed, and on cooling the bitumen hardens again. From this property it is sufficiently evident that this substance may be converted to many useful purposes, and accordingly it is universally used in the country wherever pitch is required; and the reports of the naval officers who have tried it are favourable to its more general adoption: it is requisite merely to prepare it with a proportion of oil, tallow, or common tar, to give it a sufficient degree of fluidity. In this point of view, this lake is of vast national importance, and more especially to a great maritime power. It is indeed singular that the attention of government should not have been more forcibly directed to a subject of such magnitude: the attempts that have hitherto been made to render it extensively useful have for the most part been only feeble and injudicious, and have consequently proved abortive. This vast collection of bitumen might in all probability afford an inexhaustible supply of an essential article of naval stores, and being situated on the margin of the sea could be wrought and shipped with little inconvenience or expense *. It would however be great injustice to Sir Alexander Cochrane not to state explicitly, that he has at various times, during his long and active command on the Leeward Island station, taken considerable pains to insure a proper and fair trial of this mineral production for the highly important uses of which it is generally believed to be capable. But whether it has arisen from certain perverse occurrences, or from the prejudice of the mechanical superintendants of the colonial dock-

* This island contains also a great quantity of valuable timber, and several plants which yield excellent hemp.

yards, or really, as some have pretended, from an absolute unfitness of the substance in question; the views of the gallant admiral have, I believe, been invariably thwarted, or his exertions rendered altogether fruitless. I was at Antigua in 1809, when a transport arrived laden with this pitch for the use of the dock-yard at English Harbour: it had evidently been hastily collected with little care or zeal from the beach, and was of course much contaminated with sand and other foreign substances. The best way would probably be to have it properly prepared on the spot, and brought to the state in which it may be serviceable, previously to its exportation. I have frequently seen it used to pay the bottoms of small vessels, for which it is particularly well adapted, as it preserves them from the numerous tribe of worms so abundant in tropical countries *. There seems indeed no reason why it should not when duly prepared and attenuated be applicable to all the purposes of the petroleum of Zante, a well known article of commerce in the Adriatic, or that of the district in Burmah, where 400,000 hogsheads are said to be collected annually †.

It is observed by Capt. Mallet, in his Short Topographical Sketch of the island, that "near Cape la Brea (la Braye) a little to the south-west, is a gulf or vortex, which in stormy weather gushes out, raising the water five or six feet, and covers the surface for a considerable space with petroleum or tar;" and he adds, that on the east coast in the Bay of Mayaro, there is another gulf or vortex similar to the former, which in the months of March and June produces a detonation like thunder, having some flame with a thick black smoke, which vanishes away immediately: in about twenty-four hours afterwards is found along the shore of the bay a quantity of bitumen or pitch, about three or four inches thick, which is employed with success." Captain Mallet likewise quotes Gumilla, as stating in his Description of the Oroonoco, that about seventy years ago "a spot of land on the western coast of this island, near half way

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* The different kinds of bitumen have always been found particularly obnoxious to the class of insects. There can be little doubt but that they formed ingredients in the Egyptian compost for embalming bodies, and the Arabians are said to avail themselves of them in preserving the trappings of their horses. Vide Jameson's Mineralogy.

† Vide Aikin's Dictionary of Chemistry, quoted from Captain Cox in the Asiatic Researches.

between the capital, an Indian village sank suddenly, and was immediately replaced by a small lake of pitch, to the great terror of the inhabitants."

I have had no opportunity of ascertaining personally whether these statements are accurate, though sufficiently probable from what is known to occur in other parts of the world; but I have been informed by several persons that the sea in the neighbourhood of La Braye is occasionally covered with a fluid bitumen, and in the south-eastern part of the island there is certainly a similar collection of this bitumen, though of less extent, and many small detached spots of it are to be met with in the woods: it is even said that an evident line of communication may thus be traced between the two great receptacles. There is every probability, that in all these cases the pitch was originally fluid, and has since become inspissated by exposure to the air, as happens in the Dead Sea and other parts of the East.

It is for geologists to explain the origin of this singular phænomenon, and each sect will doubtless give a solution of the difficulty according to its peculiar tenets. To frame any very satisfactory hypothesis on the subject, would require a more exact investigation of the neighbouring country, and particularly to the southward and eastward, which I had not an opportunity of visiting. And it must be remembered that geological inquiries are not conducted here with that facility which they are in some other parts of the world: the soil is almost universally covered with the thickest and most luxuriant vegetation, and the stranger is soon exhausted and overcome by the scorching rays of a vertical sun. Immediately to the southward the face of the country, as seen from La Braye, is a good deal broken and rugged, which Mr. Anderson attributes to some convulsion of nature from subterranean fires, in which idea he is confirmed by having found in the neighbouring woods several hot springs. He is indeed of opinion that this tract has experienced the effects of the volcanic power, which, as he supposes, elevated the great mountains on the main and the northern side of the island *. The production of all bituminous substances has certainly with plausibility been attributed to the action of subterranean fires on beds of coal, being separated in a similar manner as when

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* Vide Philos. Trans. vol. lxxix. or Ann. Register for 1789.

effected by artificial heat, and thus they may be traced through the various transformations of vegetable matter. I was accordingly particular in my enquiries with regard to the existence of beds of coal, but could not learn that there was any certain trace of that substance in the island; and though it may exist at a great depth, I saw no strata that indicate it. A friend, indeed, gave me specimens of a kind of bituminous shale mixed with sand, and which he brought from Point Cedar, about twenty miles distant, and I find Mr. Anderson speaks of the soil near the pitch lake containing burnt cinders, but I imagine he may have taken for them the small fragments of the bitumen itself.

An examination of this tract of country could not fail, I think, to be highly gratifying to those who embrace the Huttonian theory of the earth; for they might behold the numerous branches of one of the largest rivers of the world (the Oroonoco) bringing down so amazing a quantity of earthly particles as to discolour the sea in a most remarkable manner for many leagues distant *; they might see these earthly particles deposited by the influence of powerful currents on the shores of the Gulf of Paria, and particularly on the western side of the island of Trinidad; they might there find vast collections of bituminous substances, beds of porcelain,

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* No scene can be more magnificent than that presented on a near approach to the north-western coast of Trinidad. The sea is not only changed from a light green to a deep brown colour, but has in an extraordinary degree that rippling, confused and whirling motion, which arises from the violence of contending currents, and which prevail here in so remarkable a manner, particularly at those seasons when the Oroonoco is so swollen by periodical rains, that vessels are not unfrequently several days or weeks in stemming them, or perhaps are irresistibly borne before them far out of their destined tract. The dark verdure of lofty mountains, covered with impenetrable woods to the very summits, whence, in the most humid of climates, torrents impetuously rush through deep ravines to the sea; three narrow passages into the Gulf of Paria, between rugged mountains of brown micaceous schist, on whose cavernous sides the eddying surge dashes with fury, and where a vessel must necessarily be for some time embayed, with a depth of water scarcely to be fathomed by the lead,—present altogether a scene which may well be conceived to have impressed the mind of the navigator who first beheld it with considerable surprise and awe. Columbus made this land in his third voyage, and gave it the name of the *Bocas del Drago*. From the wonderful discoloration and turbidity of the water, he sagaciously concluded that a very large river was near, and consequently a great continent.

jasper, and such other bodies as may readily be supposed to arise from the modified action of heat on such vegetable and earthy materials as the waters are known actually to deposit. They would further perceive no very vague traces of subterranean fire, by which these changes may have been effected and the whole tract elevated above the ordinary level of the general loose soil of the country: as for instance, hot springs, the vortices above mentioned, the frequent occurrence of earthquakes, and two singular semi-volcanic mounds at Point Icaque, which, though not very near, throw light on the general character of the country. Without pledging myself to any particular system of geology, I confess an explanation similar to this appears to me sufficiently probable, and consonant with the known phænomena of nature. A vast river, like the Oroonoco, must for ages have rolled down great quantities of woody and vegetable bodies, which from certain causes,—as the influence of currents and eddies,—may have been arrested and accumulated in particular places; they may there have undergone those transformations and chemical changes which various vegetable substances similarly situated have been proved to suffer in other parts of the world. An accidental fire, such as is known frequently to occur in the bowels of the earth, may then have operated in separating and driving off the newly formed bitumen more or less combined with siliceous and argillaceous earths, which forcing its way through the surface, and afterwards becoming inspissated by exposure to the air, may have occasioned such scenes as I have ventured to describe. The only other country accurately resembling this part of Trinidad, of which I recollect to have read, is that which borders on the Gulf of Taman in Crim Tartary: from the representation of travellers, springs of naphta and petroleum equally abound, and they describe volcanic mounds precisely similar to those of Point Icaque. Pallas's explanation of their origin seems to me very satisfactory; and I think it not improbable that the river Don and Sea of Azof may have acted the same part in producing these appearances in the one case, as the Oroonoco and Gulf of Paria appear to have done in the other *. It may be supposed that the destruction of a forest, or perhaps even a great

* Vide Universal Magazine for February 1808, Mrs. Guthrie's Tour in the Tauride, or Voyages de Pallas.

savanna on the spot, would be a more obvious mode of accounting for this singular phænomenon; but, as I shall immediately state, all this part of the island is of recent alluvial formation, and the land all along this coast is daily receiving a considerable accession from the surrounding water. The pitch lake with the circumjacent tract being now on the margin of the sea, must in like manner have had an origin of no very distant date; besides, according to the above representation of Capt. Mallet, and which has been frequently corroborated, a fluid bitumen oozes up and rises to the surface of the water on both sides of the island, not where the sea has encroached on and overwhelmed the ready-formed land, but where it is obviously in a very rapid manner depositing and forming a new soil.

From a consideration of the great hardness, the specific gravity, and the general external characters of the specimens submitted a few years ago to the examination of Mr. Hatchett, that gentleman was led to suppose that a considerable part of the aggregate mass at Trinidad was not pure mineral pitch or asphaltum, but rather a porous stone of the argillaceous genus, much impregnated with bitumen. Two specimens of the more compact and earthy sort, analysed by Mr. Hatchett, yielded about 32 and 36 per cent. of pure bitumen: the residuum in the crucible consisted of a spongy, friable and ochraceous stone; and 100 parts of it afforded, as far as could be determined by a single trial, of silica 60, alumina 10, oxide of iron 10, carbonaceous matter by estimation 11; not the smallest traces of lime could be discovered; so that the substance has no similarity to the bituminous limestones which have been noticed in different parts of the world *. I have already remarked, that this mineral production differs considerably in different places. The specimens examined by Mr. Hatchett by no means correspond in character with the great mass of the lake, which in most cases, would doubtless be found to be infinitely more free from combination with earthy substances; though from the mode of origin which I have assigned to it, this intermixture may be regarded as more or less unavoidable. The analysis of the stone after the separation of the bitumen, as Mr. Hatchett very correctly observes, accords with the prevalent soil of the country; and I may add, with the soil

* Vide Linnean Trans. vol. viii.

daily deposited by the gulf, and with the composition of the porcelain jasper in immediate contact with the bituminous mass.

All the country which I have visited in Trinidad is either decidedly primitive or alluvial. The great northern range of mountains which runs from east to west, and is connected with the Highlands of Paria on the continent by the Islands at the Bocas, consists of gneiss, of mica slate containing great masses of quartz, and in many places approaching so much to the nature of talc as to render the soil quite unctuous by its decomposition, and of compact blueish gray limestone, with frequent veins of white crystallized carbonate of lime. From the foot of these mountains, for many leagues to the southward, there is little else than a thick fertile argillaceous soil, without a stone or a single pebble. This tract of land, which is low and perfectly level, is evidently formed by the *detritus* of the mountains, and by the copious tribute of the waters of the Oroonoco, which being deposited by the influence of currents, gradually accumulates; and in a climate where vegetation is astonishingly rapid, is speedily covered with the mangrove and other woods. It is accordingly observed, that the leeward side of the island constantly encroaches on the gulf, and marine shells are frequently found on the land at a considerable distance from the sea. This is the character of Naparima and the greater part of the country I saw along the coast to la Braye. It is not only in forming and extending the coast of Trinidad, that the Oroonoco exerts its powerful agency: co-operating with its mighty sister flood, the Amazons, it has manifestly formed all that line of coast and vast extent of country included between the extreme branches of each river. To use the language of a writer in the Philosophical Transactions of Edinburgh; "If you cast your eye upon the map, you will observe from Cayenne to the bottom of the Gulf of Paria this immense tract of swamp, formed by the sediment of these rivers, and a similar tract of shallow muddy coast, which their continued operation will one day elevate. The sediment of the Amazons is carried down thus to leeward (the westward) by the constant currents which set along from the southward and the coast of Brazil. That of the Oroonoco is detained and allowed to settle near its mouths by the opposite island of Trinidad, and still more by the mountains on the main, which are only separated from that island by the Bocas del Drago. The coast of Guiana has remained, as it were, the great eddy or

resting-place for the washings of great part of South America for ages; and its own comparatively small streams have but modified here and there the grand deposit*."

Having been amply gratified with our visit to this singular place, which to the usual magnificence of the West Indian landscape unites the striking peculiarity of the local scene, we re-embarked in our vessel, and stood along the coast on our return. On the way we landed, and visited the plantations of several gentlemen, who received us with hospitality, and made us more fully acquainted with the state of this island: a colony which may with truth be described as fortunate in its situation, fertile in its soil, and rich beyond measure in the productions of nature; presenting, in short, by a rare combination, all which can gratify the curiosity of the naturalist, or the cupidity of the planter; restrained in the development of its astonishing resources, only by the inadequacy of population, the tedious and ill-defined forms of Spanish justice, and the severe, though we may hope transient, pressure of the times.

[*Geological Transactions.*]

SECTION VIII.

Medical Springs, or Mineral Waters, commonly so called.

1. *Introductory Remarks.*

WATERS holding minerals in solution are usually called *mineral waters*. But as all water in a natural state is more or less impregnated with mineral substances, the name *mineral* waters should be confined to such as are sufficiently impregnated with mineral matters to produce some sensible effects on the animal economy, and either to cure or prevent some of the diseases to which the human body is liable. On this account these waters might with far more propriety be called *medicinal*, were not the name by which they are commonly known too firmly established by long use. The medicinal materials usually found in waters of this kind are gasseous acids, sulphur or sulphurets, purging salts, and metals. They are

* Vide Mr. Lochhead's Observ. on the Nat. Hist. of Guiana. Edin. Trans. vol. iv.

sometimes found of the usual temperature, and not unfrequently raised far beyond it, of which we have already given a few examples in one or two of the preceding sections. The heat, as we have also already hinted, appears sometimes from active volcanos in the immediate vicinity; and sometimes from the disengagement of subterranean gasses powerfully combined with caloric. In many instances the heat appears to be generated by the decomposition of water itself. Thus, for example, there are varieties of pyrites which are converted into sulphate of iron, by the contact of water, and such a change is accompanied by an evolution of heat. Were we to suppose the Bath spring to flow through a bed of such pyrites, its heat might be occasioned by a decomposition of this kind. Such, probably, is the way in which those mineral springs, that contain sulphureted hydrogen gas, receive their impregnation. But we are pretty certain, that such a supposition will not apply to Bath water: first, because it does not contain the quantity of sulphate of iron, which would be necessary upon such a supposition; and secondly, because instead of sulphureted hydrogen gas, which would infallibly result from such a decomposition of pyrites, there is an evolution of azotic gas. This evolution of azotic gas, however, is a decisive proof that the heat of Bath waters is owing to some decomposition or other, which takes place within the surface of the earth; though, from our imperfect acquaintance with the nature of the mineral strata, through which the water flows, we cannot give any satisfactory information as to what that decomposition actually is.

In treating this important subject in as popular a way as a somewhat exact and scientific enquiry will allow us, we shall first take a brief survey of the principal medicinal waters of foreign countries; next of those that are domestic or belong to our native soil; and then examine the general nature and proportion of the mineral substances that enter into them, and point out the means of detecting and analysing them.

EDITOR.

2. *Principal Foreign Medicinal Waters.*

IN the peninsula of Kampschatka are several hot springs, possessing very singular properties. Captain King speaks of one at

an inconsiderable ostrog, or town, called *Natcheekin*, distant thirty-eight versts, or twenty-five miles, from *Karatchin*. He says a steam rises from it as from a boiling cauldron, and the air round it has a strong sulphureous smell. The main spring forms a bason of about three feet in diameter, beside which there are a number of lesser springs, of the same degree of heat, in the adjacent ground, so that the whole spot, to the extent of near an acre, was so hot, that it was impossible to stand two minutes in the same place. The bath was reported to have performed great cures in various disorders. In the bathing place the thermometer stood at 100°, or above blood-heat; but in spring, after being immersed two minutes, it was one degree above boiling spirits; the thermometer in the air at the same time was 34°. A variety of plants were seen to grow about this spring with great luxuriance.

The BATHS of CALYPSO, in Asia Minor, are a little more than a mile from the city of Bursa, and form very handsome structures covered with domes; they are so famous for the cures which they have effected in different diseases, that people come an hundred miles to receive the benefit of them.

In Constantina, the eastern province of Algiers, near the city of this name, which in ancient times was called CIRTA, and is now the capital of the province, we meet with a group called the INCHANTED BATHS, situated on a low ground, surrounded with mountains. There are here several springs of an intense heat, and at a small distance are others extremely cold. The hot springs have a strong sulphureous steam; and Dr. Shaw observes, that the heat is so great as to boil a large piece of mutton very tender in a quarter of an hour, and that the rocky ground over which the water runs, is, for a space of an hundred feet, reduced to a state of calcination by the operation of this water in its course. He adds, that these rocks being originally soft and uniform, the water, by making equal impressions every way, leaves them in the shape of cones and hemispheres, which being six feet high, and nearly of the same diameter, the Arabs believe to be the tents of their predecessors metamorphosed into stone. And where these rocks, intermixed with their usual chalky substance, contain some layers of a harder matter, not so easily dissolved, there appears a confusion of traces and channels, forming figures which the Arabs distinguish into camels, horses, and sheep, with men, women, and children, whom

they suppose to have undergone the same fate with their habitation.

Among the Alps are several mineral springs and warm baths. In Swisserland and Germany there are four towns which bear the name of *Baden*, from the *warm baths* which render them remarkable. In BADEN, the capital of a country bordering on the canton of Zurich, the baths were famous even at the commencement of the christian æra. They are about a quarter of a mile below the town, on both sides the river Limmat. The largest of them are at Imrapen, a pretty little borough, which consists of handsome houses seated on an eminence. It is computed that the water is conveyed by no less than sixty canals to the several inns and private houses. They come from various springs by the side of the river, and it is said from one in the midst of the river itself. The waters are hot in the third degree, and impregnated with sulphur, alum, and nitre. The springs always rise to the same level, without increase or decrease, but are thought to have most virtue about the beginning of May and September, because they then abound most with the sulphuric acid.

The water is good for drinking as well as bathing, and is recommended for the cure of distempers, not only of the hot kind, as fevers, but for those proceeding from cold humours, pains in the head, vertigos, &c. disorders in the breast and bowels, asthmas and obstructions. In the centre of the place is the Poor's bath, called St. Verena's, formed by a spring that rises in the very middle of the street. Here the poor people bathe in an open situation; and its waters being esteemed a cure for sterility in women, it is said that scarce any young woman of distinction marries in this country without making it an article in the marriage-contract that her husband shall take her every year to the baths of Baden; the ladies being here permitted to wear those dresses, and allowed those diversions, that are prohibited in other parts of Swisserland, Blainville observes, that those who bathe in the public baths, are generally such as cannot afford the expense of the private ones, have their shoulders cupped in them, and that instead of cupping-glasses they use large rams or bucks-horns; so that in these baths are sometimes seen two or three hundred naked persons of both sexes, with horns on their shoulders. The people who stay at Imrapen for the use of the baths, are obliged to buy the water they

use for drinking and dressing their victuals, it being brought from Baden, or some springs on the other side of the Limmat, the water of that river being always thick and muddy, from the rapidity of its course among the rocks and sand.

PREFFERS, in Latin *Fabarium*, and in French *Faviere*, is also famous for its baths. They are seated in a valley at the bottom of two steep rocks or mountains, through which the river Tamin rushes down with a frightful noise. The crags of the rocks advance so as to form a kind of arch. The descent to the baths was first by ropes, as into a well, afterwards a passage was made down to them by wooden bridges fastened in one another, and suspended between the rocks, and then with infinite labour were built bagnios and lodging-rooms: but the buildings were so darkened by the rocks, that they were obliged to employ lighted candles in the rooms at noon-day. In 1629 these buildings were all burned down; but the next year the abbot caused others to be erected, in a pleasanter and more lightsome place, by cutting passages in the rock, and erecting wooden bridges where the earth was wanting. The water is perfectly clear, without either taste or smell. It generally rises about the beginning of May, and goes quite away about the middle of September. It is impregnated with sulphur, nitre, and several metals, particularly gold. It is hot in the second degree, and good against various distempers, particularly obstructions of the brain and nerves, pains in the head, epilepsies, deafness, weak eyes, palsy, obstructions of the viscera, fistulas, and other ulcers.

BADEN, in the neighbourhood of Vienna, is also much celebrated and resorted to on account of its warm baths. Here both sexes bathe, without distinction, in the same bath, and at the same time. The bathing clothes are made to cover the whole body; and those of the women have lead at the bottom to keep them down. There are seats within the baths for the convenience of sitting in the water, which can be raised or lowered at pleasure. The company walk up and down in the bath, conversing together, and the ladies are sometimes treated with sweetmeats. There are particular doors and stairs leading into the separate stove-rooms out of the bath where the different sexes dress and undress apart. Some of the common baths however, are within the stove rooms themselves, and in most of them the water is extremely clear. The principal is called the Women's Bath, and next to that the *Duke's*

and *Anthony's* baths. There is also one appropriated to the use of the poor. The sulphureous effluvia arising from the baths tinge most kinds of metals with yellow; and a silver cup, after being some time used for drinking the water, contracts a sort of gilding. These baths are chiefly recommended to patients afflicted with gout, lameness, pains in the joints, or any arthritic disorders.

In the Valais are the famous hot-baths called the *Baths of Leuck*; they are in a valley about two leagues distant from a village of that name, inclosed on all sides by high mountains, through which there is only a narrow passage to a wood on the south side. They are formed by five springs, not far from each other. The largest, whichfills eight baths, flows plentifully, and the water is hot enough for boiling eggs. It is for the most part clear, but sometimes changes its colour. It is purgative, and good against colds, the gout, weak stomachs, diseases of the liver, lungs, and spleen, dimness of sight, convulsions, defluxions, the dropsy, stone, ulcers, &c. There is another of the springs good against the leprosy, and at a small distance from these are several cold springs, the largest of which flows only from May to September, that is during the summer, when other springs are dried up, but this is ascribed to the melting of the snow on the Alps.

Near the lake of Bourget, in Savoy, is an alternating spring, which rises and falls with some noise, but not at stated and regular times. After Easter this alteration is frequently perceived six times in an hour; but in dry seasons not above once or twice: it issues from a rock, and is called *la Fontaine de Merveill.* omewhat similar to this are several of the springs of this country, that throw up more or less water, according to the alterations in the Rhone; but they have seldom so short and frequent a flux and reflux as in the spring just mentioned. They contain different mineral substances, but are chiefly celebrated for their flux and influx.

In Lower Hungary, the village of RIBAR is celebrated for its warm baths on a hill in its neighbourhood. About six hundred paces from it, towards the south, in a fine meadow, which makes part of a most delightful valley, is an aperture long noted for its noxious effluvia, which have not been sufficiently analyzed, but which have been found to kill both beasts and birds. A stream gushes out from it with great impetuosity, and is as rapidly absorbed. These effluvias are not poisonous to man; for the water

may be drunk, and the beasts and fowls killed by it may be safely eaten.

Aix la Chapelle, in the circle of Westphalia, has been long distinguished for mineral springs; here is a noble fountain, formed by four springs, which run from above into a copper cistern thirty feet in diameter, weighing twelve thousand pounds; and on the top of the fountain is a large brass statue, of Charlemagne in rich armour. As the city lies in a valley surrounded with mountains, there are twenty other public fountains of clear water, besides many private ones. Without St. James's gate are ten hot mineral springs, and some cold ones, beside several in the adjacent fields. The streams that run through the city keep it very clean, and drive several mills.

Of the more celebrated baths of this city, there are three within the inner walls, which are called the *Emperor's*, *St. Quirinus's*, and the *Little Bath*. Charlemagne was so much delighted with the first, that he frequently invited his sons and nobles to bathe and swim there with him; but it is now divided into five bathing-rooms. The Little Bath joins to it, and the springs of both rise so hot, that ten or twelve hours are allowed for their cooling before they can be used. They are strongly impregnated with nitre and sulphur and sulphurated hydrogen gas; and sometimes cakes of brimstone and saltpetre of a considerable thickness are taken out of them. Their taste is at first unpleasant, and their smell resembles that of a rotten egg, or of our Harrogate water. Near these baths is a spring of warm water, much resorted to in the summer mornings, and drunk for chronical diseases. Those in the New Town, which are the *Rose Bath*, the *Poor's Bath*, and *St. Cornéille's*, are by no means so hot and clear as the former; but they are of much the same nature, and their smell is as offensive. Near the hot springs lie many cold ones, by which their heat might be tempered, and with a little expense they might be made some of the most delightful baths in the world.

About the distance of a furlong from the south gate of Aix la Chapelle lies the delightful village of Porcet, or *Borcet*, which is said to have derived its name from the wild boars that formerly abounded in the neighbouring woods. Here are many hot springs, on both sides of a small cool rivulet that runs through the village,

and are conveyed by pipes and conduits into fourteen houses, in which are formed twenty-eight baths, some of which are much hotter than those in the town, and must be cooled eighteen hours before they can be used. They are for the most part five or six yards square, and their water is clear and pleasant. One quite open to the air, called "the Poor Man's Bath," has a spring so hot that the people scald pigs, and boil eggs in it. These baths are not so strong as those in the city, and are hence often preferred for the more weakly; and on this account, those of all ages and conditions bathe in them, for their diversion, without any danger.

At METHORN, two miles from Paderborn, are three springs, two of which are not above a yard asunder, and yet are of very different qualities: the one is limped, of a bluish colour, luke-warm, and contains sal-armoniac, iron, alum, sulphur, nitre, and orpiment; the other is as cold as ice, turbid, and whitish, yet has much the same contents; but the water has a stronger taste, and is heavier than the other. It is said to be a perfect cure for worms, yet the fowls that drink of it are immediately thrown into convulsions, but are soon recovered by an infusion of common salt and vinegar. The third spring, which is about twenty paces distant from the other two, is of a greenish colour, but very clear; the taste has a mixture of sweet and sour.

SPA or SPAW, a town celebrated for its mineral waters, is seated in a valley surrounded with mountains, and contains three hundred houses. The part called the *Old Spa*, which is properly only a suburb to the new, consists of a few miserable cottages; and when strangers arrive, the poor inhabitants send out a swarm of children to get what they can by begging. Even the houses of New Spa, are little, dark, old-fashioned, wooden buildings, and yet it is affirmed, that they can make twelve hundred beds for strangers. The inn called "the Court of London," is very large, and, as it is the best in the place, is chiefly frequented by strangers. The names of the five principal wells are *Tunnelet*, *Watpotz*, *Saviniere*, *Gerensterd*, and *Poubon*, all of them are strong calybeates; highly impregnated with carbonic acid gas, and some of them with lime. The inhabitants are employed in making toys, and other things for strangers, to whom they are very civil, and ready to do them all good offices.

The waters of PYRMONT are likewise in WESTPHALIA. The

citadel of Pyrmont is fortified with a broad ditch, and high ramparts: it has also subterraneous passages. From the ditch of the citadel a canal has been carried quite down to the spring, where is a mineral fountain, which rises about twenty feet high. A little above is a house in which an assembly is held, and near it is the house that encloses the spring: about forty feet distance from this fountain-head rises, with a considerable noise, the great bubbling spring, which is used for bathing; and at a hundred and twelve feet distant, to the west, issues the lower spring, which is much weaker. These springs are frequently resorted to by persons of distinction, in order to drink the waters in the highest perfection. Frederick III. of Prussia once visited them for that purpose.

At BUDA, in HUNGARY, in the suburbs of *Wasserstadt* and *Reisenstadt*, are five warm baths, the principal of which, called the *Emperor's*, is built somewhat in the manner of the Rotunda at Rome, with a large aperture in the centre of the dome, beside several small holes or windows round the cupola, for admitting more light. In a large bath, in the centre of the other four, both sexes publicly bathe together, the men wearing only a kind of drawers, and the women what they term a fore shift, but the common people, for whom one of the other baths is appointed, look upon even this slight covering as superfluous. There is also a pond of mineral water, which has this surprising property, that when the water is wholly turned off, the water-springs cease flowing; but when the pond is a little above half full, they return again.

The SELTZER waters are procured from a spring which, without flowing, rises in a well, near the town of Needer Seltzer, in the bishopric of Treves, in the circle of the Lower Rhine. It has a brisk acidulous taste when taken up from the fountain, but loses it on being exposed to the air in an open vessel. These waters operate chiefly as diuretics; they are also powerful antiseptics, and give a gentle stimulus to the nerves: they allay heat and thirst, and have been much prescribed in scorbutic, phthisical, and nervous cases; in gouty cases they are likewise drunk, from a pint, to two or three more, in a day.

Of the mineral springs in FRANCE, it will be sufficient to mention two or three.

The waters of LA MOTHE, in that part of France which until lately was named Dauphine, are highly esteemed as a remedy against

disorders of the stomach, fluxes, and even lameness, and more so indeed than the waters at Aix, in Savoy. La Mothe is a valley about five leagues from Grenoble, that runs between two high mountains, and has no other prospect but that of bare and steep rocks. The only dwellings here are wretched huts of straw, so that the country is in every respect disagreeable. The Drac, a very rapid river, proceeding from the high part of the district of Gap, is, as it were, squeezed in at La Mothe between two high rocks, previous to its falling into the Isere. On its shore, at the foot of a very steep rock, is the mineral spring, which, if the river rises but half a foot, is covered with its turbid water.

Aix, is in Latin *Aquæ Sextiæ,* and called *Aquæ* from its baths, and *Sextiæ* from its being enlarged and beautified by Sextus Calvinus. This was the first settlement made in Gaul by the Romans, a hundred and twenty-four years before Christ. This city, which was the capital of Provence, and the seat of its parliament, stands in a valley of considerable extent, planted chiefly with olives, in 43° 32′ north latitude, and 5° 26′ east longitude from Greenwich, twenty miles to the northward of Marseilles, and thirty-five to the south-east of Avignon. In its suburbs, the warm mineral spring, once so celebrated by the Romans, was found a second time in 1704, on digging for the foundation of a house. The waters are found serviceable in gout, gravel, scurvy, palsy, indigestion, asthma, and consumption. The magistrates have raised a plain building, in which are two private baths, and a bed-chamber adjoining to each. Mr. *Swinburne* observes that the waters are scarcely warm, and almost tasteless. The town is plentifully supplied with water, flowing on all sides from the impending hills. In the year 1771 an inundation overspread all the lower quarter of the city, to the height of from twelve to fifteen feet; when all the vintage was entirely destroyed, together with much cattle, and numbers of inhabitants.

In the neighbourhood of Clermont, in that part of France which untill lately was called Auverne, are wells, the waters of which possess such a quality that any substance laid on them soon contracts a stony crust. The most remarkable of these is that in the suburb of St. Allier, which has formed a famous stone bridge, mentioned by many historians. This bridge is a solid rock composed of several strata, formed during the course of many years by the run-

ning of the petrifying waters of this spring. It has no cavity or arches, till after above sixty paces in length, where the rivulet of Tiretaine forces its way through. This petrifying spring, which falls on a much higher ground than the bed of the rivulet, gradually leaves behind it some stony matter, which in process of time has thus formed an arch, through which the Tiretaine has a free passage. The necessity that this petrifying matter seems to be under of forming itself into an arch, could continue no longer than the breadth of the rivulet, after which the water of the spring ran regularly under it, and there proceeded a new petrifaction resembling a pillar. The inhabitants of these parts, in order to lengthen this wonderful bridge, have diverted the brook out of its old channel, and made it pass close by the pillar, by which means they have caused the spring to form a second arch; and thus they might have produced as many arches and pillars as they pleased; but the great resort of people to see this natural curiosity becoming troublesome to the Benedictines of the abbey of St. Allier, within whose jurisdiction the spring lies, in order to lessen its petrifying virtue, they divided the spring into several branches, which has so well answered their intent, that at present it only covers with a thin crust those bodies on which it falls perpendicularly; yet in those over which it runs in an ordinary course, no traces of its petrifying qualities are any longer perceivable. It is the only water used for drinking in this suburb, and no bad effect is felt from it.

In ITALY, at the distance of about four Italian miles from Padua, is the village of ABANO, which is much frequented in summer, on account of the warm baths at about half a mile from it. In these baths are three sorts of water, of very different qualities; some of the springs are impregnated with sulphur; others are boiling hot; and the water springs up in such quantities as to drive a mill, at the distance of about twenty paces from the source. The wooden pipes through which the water is conveyed to these baths are often encrusted with a white stony substance, not easily separated from the wood; and the exact impression of the veins and knots of the wood on this concretion, makes it perfectly resemble petrified wood. A sudatorium or sweating-bath has also been built here, the effect of which is produced by the steam of the water. Some of the springs which are tepid, are said to be impregnated with lead, while others, from their reddish sediment, and other signs, appear to be chaly-

beate. In those where sulphur predominates, the pipes contract a crust of whitish salt.

In addition to this account of gasses arising from the earth, those arising from a lake in Lapland may be very properly introduced. M. Maupertuis, who describes them, says, "the fine lakes which surround the mountain of Niemi, give it the air of an enchanted island in romance. On one hand you see a grove of trees rise from a green, smooth and level as the walks of a garden, and at such easy distances as neither to embarrass the walks nor the prospect of the lakes that wash the foot of the mountain. On the other hand are apartments of different sizes, that seem cut by art in the rocks, and to want only a regular roof to render them complete. The rocks themselves are so perpendicular, so high, and so smooth, that they might be taken for the walls of an unfinished palace, rather than for the works of nature. From this height," he adds, "we saw those vapours rise from the lake which the people of the country call *Haltios*, and deem the guardian spirits of the mountains. We had been frightened with stories of bears haunting this place, but saw none. It seemed rather, indeed, a place of resort for fairies and genii, than for savage animals."

On an island which is formed by the rivers Persante and Raduye, in Pomerania, are springs of muriate of sada, or common salt, of so strong a quality, that the inhabitants obtain from them considerable quantities of this material.

3. *Principal Domestic Mineral Waters.*

IN describing the mineral or medicinal springs which distinguish England, it will be proper to begin with those in Somersetshire.

BATH, an ancient and renowned city, is seated in a plain of moderate extent, surrounded with hills, which form a kind of amphitheatre, whence flow the springs that render this city so famous. It is situated a hundred and eight miles west of London, nineteen north-west of Wells, and twelve south-east of Bristol. It rose into consequence from its springs, which in the time of the Romans were known to possess very salubrious qualities, and their reputation is still higher than that of any other springs in England, and inferior to few in Europe. The hot springs are peculiarly beneficial to the paralytic, the gouty, and the bilious, but many other disorders are

relieved by them, on bathing, or receiving them on the part afflicted from a pump; they are chiefly used in the spring and autumn. Their waters are likewise drunk medicinally.

The city being on all sides sheltered by high hills, the air remarkably mild and salubrious, the adjacent country delightfully diversified and romantic, provisions of all kinds very abundant and cheap, with fishes in a copious variety, many persons of rank and fortune, by choosing it, or its vicinity, for their stated residence, have contributed to form it into one of the most gay and agreeable spots in the kingdom, and, in this respect, it has become a rival even to the metropolis; like which it is also continually visited, except at a very short interval in the height of summer, by the nobility and gentry of the kingdom with their attendants, gamesters, adventurers, and fortune-hunters. This fashionable resort has caused new buildings to be carried on, of late years, over a vast extent of ground, and the rage for building has at least kept pace with the demand for houses; but a great inducement to such undertakings, is the abundance of fine white stone which the quarries in the neighbourhood of the city supply. The buildings are magnificent, and many of them in a grand taste: the streets are large, well-paved, and clean; the market-place spacious, open, and supplied with the best meat, fishes, vegetables, fruits, &c. The grove, the squares, and parades, attract notice; the circus and crescent are magnificent ranges of building, and grandeur is advancing indefinitely.

Here is a neat theatre, which was erected, under the authority of an act of parliament, in the year 1768, and has ushered into notice some of the most celebrated actors of the age, particularly Henderson, and Mrs. Siddons. Here too the musical band was for some time led by Dr. Herschel, until that wonderful man renounced his profession of music, to become one of the greatest astronomers in the world.

In some places the hot and cold springs rise very near each other, and in one place within two yards. The hot springs exhale a thin kind of mist, and something of an ill smell, proceeding from the sulphureous particles combined with the water. These hot springs are always the same; for the longest and heaviest rains do not cause them to discharge more water, nor the driest seasons occasion them to discharge less.

Of these springs, that called the Cross-Bath, from a cross for-

merly erected in the middle of it, is of a moderate warmth, and a person may stay much longer in it than in any of the other baths. It is enclosed with a wall, on the sides of which are seats, and at the ends galleries for the music and spectators; under it are ranges of small dressing-rooms, one for the gentlemen, and the other for the ladies, who being dressed in linen habits, go together into the water, the men keeping on one side, and the women on the other.

The Hot-Bath, so called from its being much hotter than the Cross-Bath, is fifty-eight feet and a half distant from it. This bath has a well, whose water not only supplies its own pump, but is conveyed by pipes to the pump in the Cross-Bath.

The King's-Bath has a spring so hot that it is necessary to temper it by admitting cold water; but the heat of the hottest spring is not sufficient to harden an egg.

The Queen's-Bath has no spring of its own, but is supplied by water conveyed from the King's.

There is likewise a bath for lepers, into which none go but such as the physicians suppose to have this disease, or some other of a similar kind: this is made by the overflowing of the Cross-Bath. The poor who bathe in it have an allowance for their support from the town; but are chiefly relieved by the contributions of the gentlemen and ladies who come to enjoy the benefit of the other baths.

The following is a correct table of the temperature of the different baths, as given by Mr. John Howard, Phil. Transactions, Vol. VII. p. 201:—

King's bath pump	113°
Hot bath pump	114
Cross bath pump	108
Hot bath, coolest part	96
Ditto, warmest part	97
Pump in the hot bath	113
King's bath, coolest part	99
Ditto, hottest part	101
Queen's bath, coolest part	97
Ditto, warmest	98
Pump in the bath	113°
Cross bath, coolest part	89
Ditto, warmest part	90
Cross bath pump	107
Pump in the Market-place, Bath	54
Springs on Claverton	47
St. James's spring water	43
Springs on Lansdown	45
Old Well-house, Bristol	67
New Well, ditto	76

These temperatures were taken in the months of November and December, 1765. The scale was Fahrenheit's, and the thermometer constructed by Bird.

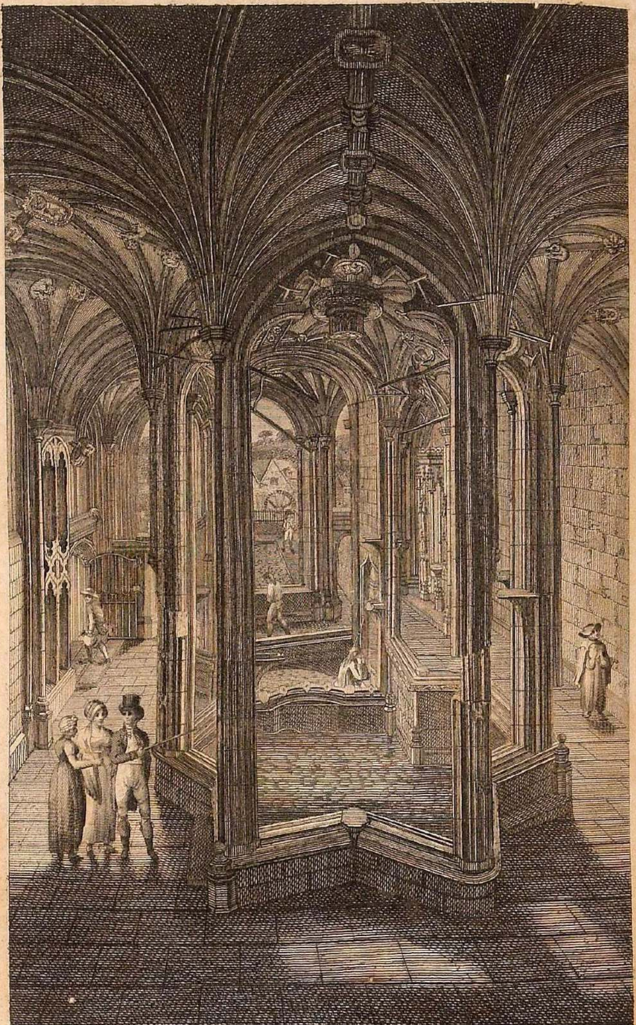
In this city there are spacious and lofty rooms for balls and

assemblies; and the studious have an easy supply of all kinds of books. There are two large stone bridges turned over the river. The stone with which the fine buildings in this city are erected is dug out of the quarries upon Charlton down, and conveyed down a steep hill, by a four-wheeled carriage of a particular form and structure; the wheels are of cast iron, broad and low, with a groove in the perimeter to keep them on the pieces of wood on which the carriage moves down hill with four or five ton weight of stone, very easily without the help of horses, the motion being moderated by means of a friction-lever bearing more or less on their hinder wheel, as occasion requires.

The walls of Bath are almost entire; the small circuit of ground encompassed by these walls is in the form of a pentagon, with four gates beside a postern. Without the walls is a handsome square, in the centre of which is an obelisk seventy feet high. The market-house is a large stone building, supported by thirty-one stone pillars, and over it is the town-hall. Here is a general hospital for the reception of the sick and lame poor from all parts of the kingdom, erected in 1738, by the contributions of the nobility and gentry of the kingdom, and is capable of containing one hundred and fifty patients. Another new square has been built in the gardens adjacent to the public walks, on the south side of the city, by the Avon, where is a noble room for balls and public assemblies.

WELLS is situated at the foot of Mendip-hills, a hundred and twenty miles west of London, and twenty south-west of Bristol, and has its name from the wells and springs about the city. It is but of small extent, though well inhabited.

BRISTOL, called by the Saxons *Brightflow*, is one hundred and seventeen miles from London, partly in Somersetshire, and partly in Glocestershire, but being a county of itself, is independent of them both. It is divided by the river Avon, which runs through it, and separates the two preceding counties, but that part which is on the Glocestershire side is the largest and most populous: according to a survey made in the year 1736, the circumference on the Glocestershire side was four miles and a half, and on the Somersetshire side two and a half. This city has a stone bridge of four broad arches over the Avon; and one of the most commodious quays in England for shipping and landing merchandise. This is the



Engraved by Angus; from a Drawing. for the Gallery of Nature & Art.

INSIDE VIEW OF S[T] WINIFRED'S WELL,

Flintshire, North Wales.

London, Published by R. Wilks, 89, Chancery Lane, Dec. 1. 1813.

second city, though some contend, the third port, in Great Britain, for trade, wealth, and number of inhabitants, Liverpool having for some years equalled and at length surpassed it in commerce.

BRISTOL HOT-WELLS are much resorted to, being considered as highly efficacious in consumptive and debilitated cases. They are at the distance of about a mile from the city, on the side of the Avon. At St. Vincent's rock, above this well, are found those native or rock crystals known by the name of Bristol stones. Near this tepid well is a cold spring, which gushes out of a rock, on the side of the river, that supplies the cold bath.

GLASTONBURY, likewise in Somersetshire, was formerly famous for its mineral waters, but having been taken incautiously and improperly, they are reported to have proved fatal to many who drank them; yet they have been found serviceable in the asthma, dropsy, scorbutic disorders, and even in cancers.

CHELTENHAM, in Glocestershire, eight miles to the south-east of Tewksbury, and eighty-nine from London, is celebrated for its mineral spring, which is a purgative chalybeate, like that at Scarborough. This town was rapidly advancing into importance in consequence of having received a visit from their Majesties in 1788; but the medical properties of its spring have varied in reputation, by the caprice of public opinion.

HOLYWELL, in Flintshire, is famous for SAINT WINIFRED'S WELL, which is one of the finest springs in the world, and on account of the sanctity in which it was held, gave name to the town. It pours out twenty-one tons of water in a minute, which running in the middle of the town, down the side of a hill, is made use of by every house as it passes, after which it turns several mills, is used in various manufactures, which greatly increase the population of the place, and its neighbourhood; the township containing more than four thousand souls. Over the spring, where there is a handsome bath, is a neat chapel, which stands upon pillars, and on the windows are painted the chief events in *St. Winifred's*, or *Wenefrede's* life. About the well grows some moss, which people foolishly imagine to be St. Winifred's hair. This Saint is reported to have been a virgin martyr, who lived in the seventh century, and as the legend says, was ravished and beheaded in this place by a pagan tyrant; the spring having miraculously risen from her blood. Hence this bath was much frequented by Popish Pilgrims, out of devotion,

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as well as by those who came to bathe in it for medicinal purposes. Mr. Pennant says, "the custom of visiting this well in pilgrimage, and offering up devotions there, is not yet entirely set aside: in the summer a few are still to be seen in the water, in deep devotion, up to their chins for hours, sending up their prayers, or performing a number of evolutions round the polygonal well. In the year 1686 James II. visited this well, and received as a reward, a present of the very shift in which his great-grandmother, Mary Queen of Scots, lost her head."

Derbyshire is the county peculiarly distinguished for its rich mines, curious appearances of nature, and salubrious fountains. Among the last, is MATLOCK'S tepid spring, which issues amidst the most delightful scenery, and is the resort of much company at the close of summer, and in the autumn.

Among the wonders of the Peak one is TIDE'S or WEEDEN'S WELL, constituting one of the class to which we have already adverted that ebb and flow like the sea. That it does ebb and flow is certain; but it is at very unequal periods, sometimes not in a day or two, and sometimes twice in an hour. The bason of the spring is about a yard deep, and the same in length and breadth. When it flows, the water rises with a bubbling noise, as if the air which was pent up within the cavities of the rock was forcing itself a passage, and driving the water before it. It is occasionally used as a restorative.

The next wonder of Derbyshire, is BUXTON WELLS, the waters of which, beside their medicinal use, have this singularity, that within five feet of one of the hot springs there arises a cold one; but this is not the only well of the kind, since hot and cold springs rise near each other in several places in England, and in other countries. These springs possess a less degree of warmth than those at Bath. The water of Buxton-wells is sulphureous, with a small quantity of saline particles, but it is not in the least impregnated with a sulphureous acid, hence they are very palatable in comparison with other medicinal waters. They are salutary in scorbutic, rheumatic, or nervous complaints, both by bathing and drinking. These waters were well known in the time of the Romans. Besides the principal springs which are at the village of Buxton, there are many others that rise unregarded in the neighbouring enclosures, and on the sides of the hill.

The Buxton waters create an appetite, and remove obstructions,

Bathing here is found beneficial in scorbutic, rheumatic, and nervous complaints. The building for the bath was erected in the reign of Queen Elizabeth, by George Earl of Shrewsbury; and here Mary Queen of Scots, when committed into his custody, resided for some time. The Duke of Devonshire, not long ago erected a beautiful building, in the form of a crescent, under which are piazzas and shops.

SCARBOROUGH is a town in the north riding of Yorkshire, two hundred and forty one miles to the north of London. Its situation is perfectly romantic, being built on the top of a steep rock, bending in the form of a crescent to the main ocean, of which an almost unbounded prospect appears from all parts. The summit of this mountain contains no less than eighteen or twenty acres of meadow ground, and on the upper part stood a castle. The town, which is populous, is almost encompassed by the sea, and walled where it does not join to the castle, or is not more strongly defended by the main; and it has one of the best harbours in the kingdom. In this town are mineral springs, which are called the "Scarborough Spa, and it is much resorted to for the purpose of sea-bathing, the shore being well accommodated for that purpose; on which account public rooms for assemblies and balls have been erected. Many merchant-ships are built here, and large contracts are made with government for the transport service. The spring, called *The Spa*, was under the cliff, part of which fell down in December 1737, by which the waters were entirely overwhelmed and concealed for some years, until upon rebuilding the wharf, the fallen fragments were removed, and the salutary waters traced to their source; a discovery which contributed greatly to enliven and enrich the town in general.

HARROWGATE, a village in the west riding of Yorkshire, twenty-one miles west of the city of York, has a mineral spring of a sulphureous quality, esteemed very salutary in scrophulous complaints. It is made use of as a bath, and is seldom taken internally. The season of resorting hither is from May to Michaelmas, when the company are accommodated in five or six commodious inns, on a heath, about a mile distant from the village.

TUNBRIDGE, in the county of Kent, received its name from the stone bridges which are thrown over the five branches of the Medway, of which the *Tun* is one, and is seated thirty miles south-

east by south of London. This place is remarkable for its chalybeate springs, which are four or five miles south of the town, but in the same parish, and are resorted to by the nobility and gentry in June, July, and August. They are situated for the most part in the parish of Tunbridge, between two hills, named *Mount Sion* and *Mount Ephraim*, both covered with good houses, and gardens abounding in fruits. Tunbridge is likewise famous for its beautiful turnery ware.

This spring was first discovered in the year 1606, and brought into general notice by Dudley Lord North, but no buildings were erected until thirty years afterward. About a mile and a half from the wells is an assemblage of stupendous rocks, from forty to seventy-five feet high, which resemble the hulks of large men of war, closely ranged.

EPSOM, in Surrey, is a handsome, well-built town, about fourteen miles from London. Its extent is about a mile and a half in a semi-circle, from the church to the fine seat at Durdans. Its mineral purgative waters, which issue from a rising ground nearer Ashted than Epsom, were discovered in 1618, and soon became very famous; but though they have not lost their virtue, they are far from being in the same repute as formerly; however, the salt made of them is valued all over Europe. A large quantity of Magnesia is prepared from the earth and water in this neighbourhood. [*Gough, Phil. Trans. Thomson.*]

4. *Means of analysing Mineral or Medicinal Waters, and of determining their Principles and Properties.*

The first knowledge of mineral waters, like every other branch of knowledge we possess, was accidentally discovered. The good effects they produced on such as use them, have doubtless been the cause of distinguishing them from common waters. The first philosophers who considered their properties, attended only to their sensible qualities, such as colour, weight, or lightness, smell, and taste. Pliny, however, distinguished a great number of waters, either by their physical properties or their uses; but the inquiry after methods of ascertaining, by chemical processes, the quantity and quality of the principles held in solution by mineral waters, was not attempted till the seventeenth century. Boyle is one of the first

who, in the valuable experiments on colours published by him at Oxford in 1663, mentioned several re-agents capable of indicating the substances dissolved in water, by the alteration produced in their colours. The Academy of Sciences, from its first institution, was aware of the importance of analysing mineral waters; and Duclos, in 1667, attempted the examination of the mineral waters of France: the researches of this chemist may be found in the original memoirs of this society. Boyle was particularly employed in inquiries respecting mineral waters about the end of the seventeenth century, and published a treatise on this subject in 1685. Boulduc, in the year 1729, published a method of analysing waters, which is much more perfect than any which were employed before his day: it consists in evaporating these fluids at different times, and separating by filtration the substances which are deposited, in proportion as the evaporation proceeds.

Many celebrated chemists have since made successful experiments on mineral waters, and almost every one made valuable discoveries respecting the different principles contained in these fluids. Bouldoc discovered natron, and determined its properties; Le Roi, physician of Montpellier, discovered calcareous muriat; Margraaff, the muriat of magnesia; Priestly, carbonic acid; and Monnet and Bergman the sulphurated or *hepatic* hydrogen gas. The two last mentioned chemists, besides the discoveries with which they have enriched the art of analysing waters, have published complete treatises on the method of proceeding in this analysis; and have carried this part of chemistry to a degree of perfection and accuracy far exceeding that which it possessed before the time of their labours. We are likewise in possession of particular analysis, made by very good chemists, of a great number of mineral waters, and which serve to throw great light on this inquiry, which, with justice, is esteemed one of the most difficult in the whole art of chemistry. The limits here prescribed do not permit us to enter at large into the history of the analysis of waters, which may be found in many treatises, especially one lately published by the celebrated Dr. Saunders.

Principles contained in Mineral Waters.—It is but a few years since the substances capable of remaining in solution in water have been accurately known. This appears to have arisen from the want of exact chemical methods of ascertaining the nature of these sub-

stances: and the certainty of their existence has naturally followed the discovery of methods of ascertaining them. Another cause which has retarded the progress of science in this respect is, that mineral matters dissolved in waters, are almost always in very small doses, and are also mixed together in considerable numbers, so that they mutually tend to conceal or alter those properties in which their distinctive characters consist. Nevertheless, the numerous experiments of the chemists before quoted, and a great number of others, which we shall occasionally mention, have shown, that some mineral substances are often found in waters, others scarcely ever met with; and lastly, many which are never held in solution by that fluid. We shall here consider each class of these substances in order.

Siliceous earth is sometimes suspended in waters; and as it is in a state of extreme division, it remains suspended without precipitating, but its quantity is extremely minute. The carbonated alkalis and chalk probably contribute to render siliceous earth soluble.

Alumine likewise appears to exist in water. The extreme subtlety of this earth, by which it is dispersed through the whole mass of water, causes it to render them turbid. Argillaceous waters are therefore whitish, and have a pearl or opal colour; they are likewise smooth, or greasy to the touch, and have been called saponaceous waters. Carbonic acid seems favourable to the suspension and solution of alumine in water.

Lime, magnesia, and barytes, are never found pure in waters; they are always combined with acids.

Fixed alkalis are never met with in a state of purity in waters, but frequently combined with acids, in the form of neutral salts.

The same observation applies to ammoniac, and most acids, except the carbonic acid, which is often free, and in possession of all its properties in waters. It constitutes a peculiar class of mineral waters, known by the name of *gaseous*, *spirituous*, or *acidulous* waters.

Among the neutral salts, with basis of fixed alkalis, scarcely any are met with but sulphat of soda or *Glauber's salt*, the muriats of soda, and of potash, and carbonat of soda, which are frequently dissolved in mineral waters; nitrat and carbonat of potash are rarely found.

Sulphat of lime, calcareous muriat, chalk, sulphat of magnesia,

or *Epsom salt*, muriat of magnesia, and carbonat of magnesia, are the earthy salts which are most commonly found in waters. As to the calcareous nitrat, and nitrat of magnesia, which some chemists have asserted they have met with, these salts are scarcely ever found in mineral waters properly so called, though they exist in salt waters.

The aluminous neutral salts, and salts with base of barytes, are scarcely ever dissolved in waters. Alum or acid sulphat of alumine, appears to exist in some waters.

Pure hydrogen gas has not yet been found dissolved in mineral waters.

Pure sulphur has not yet been found in these fluids, though it exists very rarely in small quantities in the state of sulphure of soda. Sulphureous waters are most commonly mineralized by sulphurated hydrogen gas.

Lastly: Among metals, iron is most commonly dissolved in water, and may be found in two states; either combined with carbonic acid, or with the sulphuric acid. Some chemists have supposed that it was likewise dissolved in its metallic state, without an acid intermedium; but as this metal scarcely ever exists in nature without being in the state of oxyd, combined with the carbonic or sulphuric acid, the opinion of these philosophers could only be maintained at the time when the carbonic acid was not yet discovered; and the solution of iron in water, without the assistance of the sulphuric acid, could not otherwise be accounted for. Bergman affirms, that iron, as well as manganese, is found in certain waters, combined with the muriatic acid.

Oxyd of arsenic, and the sulphats of copper and zinc, which exist in many waters, communicate poisonous properties to them, and show, when discovered by analysis, that the use of such waters must be carefully avoided.

Most chemists at present deny the existence of bitumen in waters: in fact, the bitter taste was the cause why waters were formerly supposed to contain this oily substance; but it is now known that this taste, which does not exist in bitumen, is produced by the calcareous muriat.

There is no difficulty in conceiving how water, which percolates through the interior parts of the globe, and especially through the mountains, may become charged with the different substances we

have enumerated. It is likewise clear, that according to the nature and extent of the strata of earth, through which they pass, mineral waters will be more or less charged with these principles, and that the quantity and nature of these principles must be subject to great variations, especially when we consider the changes in the direction of their course to which these fluids are liable from the various alterations which the globe undergoes, particularly on its surface and its more elevated parts.

The different Classes of Mineral Waters.—It appears from what we have already observed respecting the different substances usually contained in mineral waters, that these fluids may be classed according to the earthy, saline, and metalic substances they hold in solution; and that the number of classes, on this principle, would be very considerable: but it must be observed, that none of these substances are found single and alone in waters; but, on the contrary, they are often dissolved, in the number of three, four, five, or even more. This circumstance creates a difficulty in the methodical classification of waters, relative to the principles that they contain. However, if we attend to those substances which are the most abundantly contained in waters, or whose properties are the most prevalent, we shall be able to make a distinction, which, though not very accurate, will be sufficient to arrange these fluids, and to form a judgment of their virtues. Chemists who have attended to mineral waters in general, have availed themselves of this method. Monnet has established three classes of mineral waters; the alkaline, the sulphureous, and the ferruginous; and subsequent discoveries have enlarged the number of classes. Duchanoy, who has published a valuable treatise on the art of imitating mineral waters, distinguishes ten, viz. the gaseous, the alkaline, the earthy, the ferruginous, the simple hot, the gaseous thermal, the saponaceous, the sulphureous, the bituminous, and the saline waters. Although it may be urged as a reproach, that this author has made his classes two numerous, since the pure gaseous and bituminous waters are unknown; yet his division is doubtless the most complete, and gives the most accurate idea of the nature of the different mineral waters, and consequently is the best suited to his subject. We shall here propose a division less extensive, and in our opinion more methodical, than that of Duchanoy; at the same time observing, that we do not consider simple thermal waters as mineral waters, because they consist merely of heated water, ac-

cording to the best chemists; and that we shall not speak of bituminous waters, because none such have been yet found.

It appears to us, that all mineral waters may be arranged in four classes, viz. acidulous, saline, sulphureous, and ferruginous waters.

Acidulous Waters.—Gaseous waters, which may with more propriety be called acidulous waters, are those in which the carbonic acid predominates; they are known by their sharp taste, and the facility with which they boil and afford bubbles by simple agitation: they redden the tincture of turnsole, precipitate lime water and alkaline sulphures. As no waters have yet been discovered which contain this acid pure and alone, we think this class may be divided into several orders, according to the other principles contained in them, or the modifications they exhibit. They all appear to contain more or less alkali and calcareous earth; but their different degrees of heat afford a good criterion for dividing them into two orders; the first might comprehend cold, acidulous, and alkaline waters, such as those of Seltzer, Saint-Myon, Bard, Langeac, Chateldon, Vals, &c. in the second might be placed, hot, or thermal, acidulous, and alkaline waters, as those of Mount D'Or, Vichy, Chatelguyon, &c.

Saline or Salt Waters.—By the name of saline waters, we understand such as contain a sufficient quantity of natural salt to act strongly on the animal economy, so as most commonly to purge. The theory and nature of these waters are easily discovered; they perfectly resemble the solutions of salt made in our laboratories; but they almost always contain two or three different species of salts. The sulphat of soda is very rare; sulphat of magnesia, Epsom salt, marine salt, or muriat of soda, calcareous and magnesian muriats, or the saline principles which mineralize them, either together or separate. The waters of Sedliz, of Seydschutz, and of Egra, abound with Epsom salt, frequently mixed with muriat of magnesia. Those of Balaruc contain muriat of soda, chalk, and the calcareous and magnesian muriats; those of Bourbonne, muriat of soda, sulphat of lime and chalk; and those of la Mothe contain muriat of soda, sulphat of lime, chalk, sulphat of magnesia, muriat of magnesia, and an extractive matter. It must be here observed that salts, with base of magnesia, are much more common in waters than has hitherto been supposed; and that few analyses have yet

been made in which they have been well distinguished from calcareous muriat.

Sulphureous Waters.—The name of sulphureous waters has been given to such mineral waters as appear to possess some of the properties of sulphur; such as the smell, and the property of discolouring silver. Chemists have long been ignorant of the true mineralizer of these waters; most have supposed it to be sulphur, but they never succeeded in exhibiting it, or at least have found it in quantities scarcely perceptible. Those who have made experiments on some of these waters have allowed them to contain either sulphureous spirit, or an alkaline sulphur. Venel and Monnet are the first who opposed this opinion; the latter, in particular, nearly discovered the truth, when he considered sulphureous waters as impregnated merely by the vapour of *liver of sulphur*. Rouelle the younger likewise affirmed, that these fluids might be imitated by agitating water in contract with *air*, disengaged from an alkaline sulphure by an acid. Bergman carried this doctrine much farther, by examining the properties of sulphurated hydrogen gas, he has proved that this gas mineralizes sulphureous waters, which he therefore called *hepatic waters*, and has directed methods of ascertaining the presence of sulphur. Notwithstanding these discoveries, Duchanoy, speaking of sulphureous waters, admits of sulphur, sometimes alkaline, sometimes calcareous, or aluminous. He follows the opinion of Le Roy of Montpillier, who proposed a sulphure with base of magnesia in imitating these waters. It appears in fact to be true, that there are waters which contain a small quantity of sulphur, while there are others which are mineralized only by sulphurated hydrogen gas. In this case it will be necessary to distinguish sulphureous waters into two orders: 1. Those which contain a small quantity of alkaline or calcareous sulphur; and, 2. Those which are only impregnated with sulphuric hydrogen gas. The waters of Bareges and Cauterets, and the Bonnes waters, appear to belong to this first order; and those of St. Amant, Aix la Chapelle, and Montmorency, appear to belong to the second. Most of these waters are thermal, but that of Montmorency is cold.

Ferruginous Waters.—Iron being the most abundant of metals, and the most susceptible of alteration, it is not to be wondered at that water easily becomes charged with it, and consequently that the ferruginous waters are the most abundant and most common

of all mineral waters. Modern chemistry has thrown great light on this class of waters; they were formerly supposed to be all impregnated with sulphat of iron. Monnet has ascertained that most of them do not contain this salt, and he supposed that the iron is dissolved without the intermedium of an acid. It is at present known, that the iron is not in the state of sulphat, but is dissolved by means of the carbonic acid, and forms the salt which we have called carbonat of iron. Lane, Rouelle, Bergman, and many other chemists, have put this out of doubt. The greater or less quantity of carbonic acid, and the state of the iron in waters of this kind, render it necessary to distinguish the present class into three orders.

The first order comprehends martial acidulous waters, in which the iron is held in solution by the carbonic acid, whose superabundance renders them brisk and subacid. The waters of Bussang, Spa, Pyrmont, Pouhon, and La Dominique de Vals, are of this first order.

The second contains simple martial waters in which the iron is dissolved by the carbonic acid, without excess of the latter. These waters consequently are not acidulous. The water of Forges, Aumale, and Condé, as well as the greater number of ferruginous waters, are of this order; this distinction of ferruginous waters was made by Duchanoy.

But we add a third order, after Monnet, which is that of waters containing sulphat of iron. Though these are extremely rare, yet some of them are found. Monnet has placed the waters of Passy in this order. Opoix admits the sulphate of iron, even in a considerable quantity, in the waters of Provins. It is true, that De Fourcy denies its existence, and considers the iron of these waters as dissolved by carbonic acid. But no decision can be made respecting this subject, because the results of these chemists entirely disagree, and require new experiments to be made. It must be added, that the iron is not found alone in these waters, but is mixed with chalk, sulphat of lime, various muriatic salts, &c. However, as the metal they contain is the principal basis of their properties, they must be called ferruginous, in conformity with the principles we have laid down.

As to the saponaceous waters admitted by Duchanoy, we must wait till chemical and medical experiments have ascertained the

cause of their saponaceous property, which this physician attributes to alumine; as well as the effects they may produce in the animal economy, as medicines, by virtue of this property.

From these details we find, that all mineral and medicinal waters are divided into nine orders, viz.

Cold acidulous waters.
Hot or thermal acidulous waters.
Sulphuric saline waters.
Muriatic saline waters.
Simple sulphureous waters.
Sulphurated gaseous waters.
Simple ferruginous waters.
Ferruginous and acidulous waters.
Sulphuric ferruginous waters.

Examination of Mineral Waters, according to their Physical Properties.—After having shewn the different matters which may be found in waters, and exhibited a slight sketch of the method in which they may be divided into classes and orders, according to their principles, it will be necessary to mention the methods of analysing them, and discovering with the greatest possible degree of accuracy, the substances they hold in solution. This analysis has been justly considered as the most difficult part of chemistry, since it requires a perfect knowledge of all chemical phenomena, joined to the habit of making experiments. To obtain an accurate knowledge of the nature of any water proposed to be examined, 1. The situation of the spring, and the nature of the soil, more especially with respect to mineral strata, must be carefully observed; for this purpose, cavities may be dug to different depths, in order to discover, by inspection, the substances with which the water may be charged. 2. The physical properties of the water itself, such as its taste, smell, colour, transparence, weight, and temperature, must next be examined; for this purpose, two thermometers, which perfectly agree, and a good hydrometer, must be provided. These preliminary experiments require likewise to be made in the different seasons, different times of the day, and especially in different states of the atmosphere; for a continuance of dry weather, or of abundant rain, has a singular influence on waters. These first trials usually show the class to which the water under examination may

be referred, and direct the method of analysis. 3. The depositions formed at the bottom of the basons, the substances which float on the water, and the matters which rise by sublimation, form likewise an object of important research, which must not be neglected. After this preliminary examination, the proper analysis may be proceeded on, which is made after three methods, by re-agents, by distillation, and by evaporation.

The Examination of Mineral Waters, by Re-agents.—Those substances, which are mixed with waters, in order to discover the nature of the bodies, held in solution by such waters, from the phænomena they present, are called re-agents.

The best chemists have always considered the use of re-agents as a very uncertain method of discovering the principles of mineral waters. This opinion is founded on the considerations that their effects do not determine, in an accurate manner, the nature of the substances held in solution in waters; that the cause of the changes which happen in fluids by their addition is often unknown: and that in fact, the saline matters usually applied in this analysis are capable of producing a great number of phenomena, respecting which it is often difficult to form any decision. For these reasons, most chemists who have undertaken this analysis, have placed little dependence on the application of re-agents. They have concluded, that evaporation affords a much surer method of ascertaining the nature and quantity of the principles of mineral waters; and it is taken for granted, in the best works on the analysis of these fluids, that re-agents are only to be used as secondary means, which at most serve to indicate or afford a probable guess of the nature of the principles contained in waters; and for this reason, modern analysts have admitted no more than a certain number of re-agents, and have greatly diminished the list of those used by the earlier chemists.

But it cannot be doubted at present, that the heat required to evaporate the water, however gentle it may be, must produce sensible alterations in its principles, and change them in such a manner, as that their residues, examined by the different methods of chemistry, shall afford compounds differing from those which were originally held in solution in the water. The loss of the gaseous substances, which frequently are the principal agents in mineral waters, singularly changes their nature, and besides causing a precipi-

tation of many substances, which owe their solubility to the presence of these volatile matters, likewise produces a re-action among the other fixed matters, whose properties are accordingly changed. The phenomena of double decompositions which heat is capable of producing between compounds that remain unchanged in cold water, cannot be estimated and allowed for, but in consequence of a long series of experiments not yet made. Without entering, therefore, more fully into these considerations, it will be enough to observe, that this assertion, whose truth is admitted by every chemist, sufficiently shows, that evaporation is not entirely to be depended on. Hence it becomes a question, whether there be any method of ascertaining the peculiar nature of substances dissolved in water without having recourse to heat; and whether the accurate results of the numerous experiments of modern writers afford any process for correcting the error which might arise from evaporation. The following pages extracted from a memoir communicated by M. Fourcroy to the Royal Society of Medicine, will show, that very pure re-agents used in a peculiar manner, may be of much greater use in the analysis of mineral waters than has hitherto been thought.

Among the considerable number of re-agents proposed for the analysis of mineral waters, those which promise the most useful results are tincture of turnsole, syrup of violets, lime-water, pure and caustic potash, caustic ammoniac, concentrated sulphuric acid, nitrous acid, prussiat of lime, gallic alkohol, or *spirituous tincture of nut-galls*, the nitric solutions of mercury and of silver, paper coloured by the aqueous tincture of fernambouc, which becomes blue by means of alkalis, the aqueous tincture of *terra merita*, which the same salts convert to a brown red, the oxalic acid to exhibit the smallest quantity of lime, and the muriat of barytes to ascertain the smallest possible quantity of sulphuric acid.

The effects and use of these principal re-agents have been explained by all chemists, but they have not insisted on the necessity of their state of purity. Before they are employed, it is of the utmost importance perfectly to ascertain their nature, in order to avoid fallacious effects. Bergman has treated very amply of the alterations they are capable of pruducing. This celebrated chemist affirms, that paper coloured with the tincture of turnsole becomes of a deeper blue by alkalis; but that it is not altered by the carbonic acid. But as this colouring matter is useful chiefly to ascertain

the presence of this acid, he directs its tincture in water to be used, sufficiently diluted, till it has a blue colour. He absolutely rejects syrup of violets, because it is subject to ferment, and because it is scarcely ever obtained without adulteration in Sweden. Morveau adds in a note, that it is easy to distinguish a syrup coloured by turnsole, by the application of corrosive sublimate, which gives it a red colour, while it converts the true syrup of violets to a green.

Lime-water is one of the most useful agents in the analysis of mineral waters, though few chemists have expressly mentioned it in their works. This fluid decomposes metallic salts, especially sulphat of iron, whose metallic oxyde it precipitates; it separates alumine and magnesia from the sulphuric and muriatic acids, to which these substances are frequently united in waters. It likewise indicates the presence of carbonic acid, by its precipitation. M. Gioanetti, a physician of Turin, has very ingeniously applied it to ascertain the quantity of carbonic acid contained in the water of St. Vincent. This chemist, after having observed that the volume or bulk of this acid, from which its quantity has always been estimated, must vary, according to the temperature of the atmosphere, mixed nine parts of lime-water with two parts of the water of St. Vincent: he weighed the *calcareous earth* formed by the combination of the carbonic acid of the mineral water with lime, and found, according to the calculation of Jaquin, who proves the existence of thirteen ounces of this acid in thirty-two ounces of chalk, that the water of St. Vincent contained somewhat more than fifteen grains. But as the lime-water may seize the carbonic acid united with the fixed alkali, as well as that which is at liberty, M. Gioanetti, to ascertain more exactly the quantity of this last, made the same experiment with water deprived of its disengaged acid by ebullition. This process may therefore be employed to determine, in an easy and accurate manner, the weight of disengaged carbonic acid, contained in a gaseous mineral water.

One of the principal reasons which have induced chemists to consider the action of re-agents in the analysis of mineral waters as very fallacious, is, that they are capable of indicating several different substances held in solution in waters, and that it is then very difficult to know exactly the effects they will produce. This observation relates more especially to potash, considered as a re-agent, because it decomposes all the salts which are formed by the union

of acids with alumine, magnesia, lime, and metals. When this alkali precipitates a mineral water, it cannot, therefore, be known by simple inspection or the precipitate, of what nature the earthy salt decomposed in the experiment may be. Its effect is still more uncertain, when the alkali made use of is saturated with carbonic acid, as is most commonly the case, since the acid to which it is united, augments the confusion of effects: for this reason, the use of very pure caustic potash is proposed, which likewise possesses an advantage over the effervescent alkali, viz. that of indicating the presence of chalk dissolved in a gaseous water, by virtue of the superabundant carbonic acid: for it seizes this acid, and the chalk falls down of course. This fact is established by pouring soap lees newly made, into an artificial gaseous water, which holds chalk in solution. The latter substance is precipitated in proportion as the caustic fixed alkali seizes the carbonic acid which held it in solution. By evaporating the filtrated water to dryness, carbonat of soda is obtained, strongly effervescent with acids. The caustic fixed alkali likewise occasions a precipitate in mineral waters, though they do not contain earthy salts; for if they contain an alkaline neutral salt, of a less soluble nature, the additional alkali will precipitate it by uniting with the water, nearly in the same manner as alkohol does. M. Gioanetti has observed this phenomenon in the waters of St. Vincent; and it may easily be seen by pouring caustic alkali into a solution of sulphat of potash, or muriat of soda; these two salts being quickly precipitated.

Caustic ammoniac is in general less productive of error when mixed with mineral waters; because it decomposes only salts, with base of alumine or magnesia, and does not precipitate the calcareous salts. It is necessary, however, to make two observations respecting this salt: the first is, that it must be exceedingly caustic, or totally deprived of carbonic acid; without this precaution, it decomposes calcareous salts by double affinity: the second is, that the mixture must not be left exposed to the air, when the effect of its action is required to be inspected several hours after it is added; because, as M. Gioanetti has well observed, this salt in a very short time seizes the carbonic acid of the atmosphere, and becomes capable of decomposing calcareous salts. To put this important fact out of doubt, Fourcroy made three decisive experiments; some grains of sulphat of lime, formed of transparent calcareous spar,

because chalk, or Spanish white, contains magnesia and river water: he divided this solution into two parts; into the first he poured a few drops of very pure sulphuric acid, recently made, and very caustic; this he put into a well-closed bottle: at the end of twenty-four and forty-eight hours it was clear and transparent, without any precipitate, and therefore no decomposition had taken place. The second portion was treated in the same manner with ammoniac, but placed in a vessel which communicated with the air by a large aperture; at the end of a few hours a cloud was formed near the upper surface, which continually increased, and was at last precipitated to the bottom. This deposition effervesced strongly with sulphuric acid, and formed sulphat of lime. The carbonic acid contained in this precipitate was therefore afforded by the ammoniac which had attracted it from the atmosphere. This combination of carbonic acid and ammoniac forms ammoniacal carbonat, capable of decomposing calcareous salts by double affinity, as Black, Jacquin, and many other chemists have shown, and as may be easily proved by pouring a solution of ammoniacal carbonat into a solution of sulphat of lime, which is not rendered turbid by caustic ammoniac. Lastly, to render the theory of this second experiment clearer, Fourcroy took the first portion to which the caustic ammoniac had been added, and which, having been kept in a close vessel, had lost no part of its transparency. He reversed the bottle which contained it, over a funnel of a very small pneumato-chemical apparatus, and by the assistance of a syphon, passed into it carbonic acid gas, disengaged from the effervescent fixed alkali by sulphuric acid. In proportion as the bubbles of this acid passed through the mixture, it became turbid in the same manner as lime-water; by filtration a precipitate was separated, which was found to be chalk, and the water, by evaporation, afforded ammoniacal sulphat: gaseous water, or the liquid carbonic acid, produced the same composition in another mixture of sulphat of lime, and caustic ammoniac. This decisive experiment clearly shows, that ammoniac decomposes sulphat of lime by double affinity, and by means of the carbonic acid. Hence we see, that when it is required to preserve a mixture of the mineral water with ammoniac for several hours (which is sometimes necessary, because it does not decompose certain earthy salts, but very slowly), the experiment must be made in a vessel which can be accurately closed, in order to prevent the contact of air, which

would falsify the result. This precaution, which is of great importance in the use of all re-agents, is likewise mentioned by Bergman and Gioanetti. To these may be added another observation concerning the use of ammoniac. As it is a matter of considerable difficulty to preserve ammoniac in the state of perfect causticity, though it is necessary to be had in such a state, for the analysis of mineral waters, a very simple expedient may be applied in this case. It is to pour a small quantity of ammoniac into a retort, whose neck is plunged in the mineral water; when the retort is slightly heated, the ammoniacal gas becomes disengaged, and passes highly cautic into the water. If it occasions a precipitate, it may be concluded that the mineral water contains sulphat of iron, which may be known by the colour of the precipitate, or otherwise that it contains salts, with base of aluminous or magnesian earth. Generally this precipitate is formed by the chalk which was held in solution in the water, by means of the carbonic acid; ammoniac absorbs this acid, and the chalk is deposited. It is difficult to determine from the physical properties of the earthy precipitate formed in waters by caustic ammoniac, to which of the two last bases it is to be attributed; yet the manner in which it is formed may serve to decide. Six grains of sulphat of magnesia were dissolved in four ounces of distilled water, and six grains of alum in an equal quantity of the same fluid; through each of these solutions a small quantity of ammoniacal gas was passed: the first solution immediately became turbid, while the latter did not begin to exhibit a precipitate till twenty minutes after. These mixtures were carefully included in well closed bottles. The same phenomenon took place with the nitrats and muriats of magnesia and alumine, dissolved in equal quantities of distilled water, and treated in the same manner. The quickness or slowness of the precipitation of a mineral water by the addition of ammoniacal gas, therefore affords the means of ascertaining the nature of the earthy salt decomposed by this gas. In general, salts, with base of magnesia, are much more usually met with than those with base of aluminous earth. Bergman has observed, that ammoniac is capable of forming with sulphat of magnesia a compound in which a portion of this neutral salt is combined, without decomposition, with a portion of ammoniacal sulphat. This non-decomposed portion of sulphat of magnesia may probably form, with the ammoniacal sulphat,

a mixed neutral salt, similar to the ammoniaco-mercurial muriat, or *sal alembroth*. The ammoniac does not, therefore, precipitate the whole of the magnesia, and consequently does not accurately exhibit the quantity of *Epsom salt*, of which that earth is the base. For this reason lime-water is preferable for ascertaining the nature and quantity of salts with base of magnesia contained in mineral waters. It has likewise the property of precipitating the salts with aluminous base much more abundantly and readily than ammoniacal gas.

The concentrated sulphuric acid precipitates a white powder from water which contains barytes, according to Bergman; but, as the same chemist observes, that this earth is seldom found in mineral waters, it will not be necessary to enlarge on the effects of this re-agent. When it produces an effervescence, or bubbles in water, it indicates the presence of chalk, carbonat of soda, or pure carbonic acid; each of these substances may be distinguished by certain peculiar phenomena. If water containing chalk be heated after the addition of sulphuric acid, a pellicle and deposition of sulphat of lime are soon formed, which does not happen with waters which are simply alkaline. At first consideration it may seem that the sulphat of lime ought to be precipitated as often as the sulphuric acid is poured into water containing chalk; this, however, very seldom happens without the assistance of heat, because these waters most commonly contain a superabundance of carbonic acid, which favours the solution of the sulphat of lime, and of which it is necessary to deprive them before the salt can be precipitated. This fact may be shown in the clearest manner, by pouring a few drops of concentrated sulphuric acid into a certain quantity of lime water which has been precipitated, and afterwards rendered clear by the addition of carbonic acid: if the lime-water be highly charged with regenerated calcareous earth, a precipitate of sulphat of lime is thrown down in a few minutes, or more slowly in proportion as the carbonic acid is set at liberty: If no precipitate be afforded by standing, as will be the case when the quantity of sulphat of lime is very small, and the superabundant carbonic acid considerable, the application of a slight degree of heat will cause a pellicle of calcareous sulphat, and a precipitate of the same nature to be formed.

The nitrous acid is recommended by Bergman to precipitate sulphur from *hepatized* waters. The experiment may be made by

pouring a few drops of the brown and fuming acid on distilled water, in which the gas disengaged from caustic alkaline sulphure, heated in a retort, has been received. This artificial *hepatic* water, which does not considerably differ from natural sulphureous waters, except in the circumstance of its being more difficult to filter, and its always appearing somewhat turbid, affords a precipitate in a few seconds, by the addition of nitrous acid; the precipitate is of a yellowish white; when collected on a filter and dried, it burns with the flame and smell of sulphur, and in other respects has every character of that inflammable body. Nitrous acid seems to alter sulphurated hydrogen gas in the same manner as it does all other inflammable substances, by virtue of the great quantity of oxygen it contains. Scheele has recommended the oxygenated muriatic acid to precipitate the sulphur from waters of this nature: only a very small quantity of it must be used, otherwise the sulphur will be burned and reduced to the state of sulphuric acid. Sulphureous acid precipitates the sulphur very readily from waters which contain it.

There are few re-agents whose mode of action is less known than that of the alkaline lixivium of blood, which has been called *phlogisticated alkali*; it has been long since ascertained, that this liquor contains Prussian blue, or prussiat of iron, ready formed; it has been thought that this blue might be separated by the addition of an acid; and in this state it has been proposed as a substance capable of exhibiting iron existing in mineral waters. Nothing can be more uncertain than the complete separation of prussiat of iron from this prussiat of potash made with blood. This lixivium ought therefore to be no longer used as a re-agent. Macquer having discovered that Prussian blue is decomposed by alkalis, proposed potash saturated with the colouring matter of this blue, as a test to ascertain the presence of iron in mineral waters. But as the liquor itself likewise contains a small quantity of Prussian blue, which may be separated by means of an acid, as Macquer has shown, Baumé advises that two or three ounces of distilled vinegar be added to each pound of this Prussian alkali, and digested in a gentle heat, till the whole of the Prussian blue is precipitated; after which pure fixed alkali is to be added to saturate the acid of vinegar. Notwithstanding this ingenious process, Fourcroy has observed, that the Prussian alkali, purified by vinegar, deposits Prussian blue in process of time, more especially

by evaporation. M. Gioanetti made the same observation by evaporating the Prussian alkali, purified, by the method of Baumé, to dryness: he has proposed two processes for obtaining this liquor in a state of purity, and totally exempt from iron; the one consists in supersaturating the Prussian alkali with distilled vinegar, evaporating it to dryness by a gentle heat, dissolving the remaining mass in distilled water, and filtrating the solution; all the Prussian blue remains on the filter, and the liquor which passes through contains none at all. The other process consists in neutralizing the alkali with a solution of alum, from which after filtrating, the sulphat of potash is separated by evaporation. These two liquors do not afford a particle of Prussian blue with the pure acids, nor by evaporation to dryness. The lime water, saturated with the colouring matter of Prussian blue, which is a prussiat of iron, does not require these preliminary operations: when poured on a solution of sulphat of iron, it immediately forms pure Prussian blue, without any mixture of green. Acids only precipitate a few particles of Prussian blue from this re-agent; it therefore does not contain iron, and consequently is preferable to the Prussian alkalis, in the assay of mineral waters. This phenomenon doubtless depends on the action of the lime, which, when dissolved in water, is far from having the same efficacy on iron as alkalis have. This prussiat of lime seems to be exceedingly well adapted to distinguish ferruginous waters, whether they be gaseous or sulphuric. In fact, the carbonic gas, which holds iron in solution in waters, being of an acid nature, decomposes Prussian lixiviums by the way of double affinity, as well as sulphat of iron. Fourcroy tried prussiat of lime on Spa waters, and those of Passy, and he immediately obtained a very perceptible blue in the former, and very abundant in the latter. This, therefore, is a liquor very easily prepared, which does not contain the smallest portion of Prussian blue, and is exceedingly well calculated to exhibit the presence of small quantities of iron in waters. It is a kind of neutral salt, formed by the prussic acid, or the colouring part of the blue and lime.

Nut-galls, as well as all other bitter and astringent vegetables, such as oak bark, the fruit of the cypress tree, the husks of nuts, &c. have the property of precipitating solutions of iron, and exhibiting that metal of different colours, according to its quantity, its state, and that of the water in which it is dissolved. This colour

in general is of all shades, from a pale rose to the deepest black. It is well known that the purple colour assumed by waters, with the tincture of nut-galls, is not a proof that they contain iron in its metallic state, since the sulphat and carbonat of iron likewise assumes a purple colour by the infusion of nut-galls. The differences of colour observed in these precipitations, depend rather on the quantity of iron, its greater or less degree of adhesion to the water, and the more or less advanced state of deposition of the solution, relatively to the quantity of oxygen contained in the iron. The astringent principle is known to be a peculiar acid, since it unites with alkalis, converts blue vegetable colours to a red, decomposes alkaline sulphures, and combines with metallic oxyds. Nut-galls in powder, the infusion of this substance in water, made without heat, and the tincture by alkohol, are used to ascertain the presence of iron in mineral waters. The tincture is preferred, because it is not subject to become mouldy as the aqueous solution is. The distilled products of nut-galls likewise colour ferruginous solutions. The infusions in acids, alkalis, oils, and ether, exhibit the same phenomenon. The iron precipitated by this matter from acids is in the state of gallat of iron, and forms a kind of neutral salt, which, though very black, is not attracted by the magnet. It dissolves slowly, and without sensible effervescence in acids, but loses these properties by the action of fire, and is then attracted by the magnet. The nut-gall is so efficacious a re-agent, that a single drop of its tincture colours, in the space of five minutes, with a purple tinge, three pints of water, which contains only the twenty-fifth part of a grain of sulphat of iron. All these pheuomena proceed from the great facility with which the matter of nut-galls burns, and from its readily absorbing from the iron a portion of the oxygen it contains, passing by this means to the state of a black oxyd or ethiops, the smallest quantity of which is very perceptible in transparent liquors.

The two last reagents, we shall propose for the examination of waters, are solutions of silver and of mercury in the nitric acid. These have usually been employed to exhibit the presence of the sulphuric, or muriatic acids in mineral waters; but many other substances, which do not contain the smallest portion of those, are likewise precipitated by these solutions. The white and heavy striæ which the nitrat of silver exhibits in water, that contains no

more than half a grain of muriat of soda in the pint, ascertains the presence of the muriatic acid with great certainty and facility; but they do not in the same manner indicate the presence of the sulphuric acid, since, according to Bergman's estimate, at least thirty grains of sulphat of soda must exist in the pint of water, in order to produce an immediate sensible effect. To this we may add, that fixed alkali, chalk, and magnesia, precipitate the nitric solution of silver in a much more evident manner, and consequently that the precipitation formed in a mineral water by this solution is insufficient to determine with precision, the saline or earthy substances from which it arose.

The solution of mercury by the nitric acid, is still more productive of error: it not only indicates the presence of the sulphuric and muriatic acids in waters, but it is likewise precipitated by the earthy and alkaline carbonats, in a yellowish powder, which might be mistaken for an effect of the sulphuric acid. It has been commonly supposed, that the very abundant white precipitate which it forms in water, is owing to the presence of a muriatic salt; yet mucilaginous and extractive substances exhibit the same phenomenon, as is now well known to all chemists. Besides, these sources of error and uncertainty, dependent on the property which several substances have, of producing similar precipitates with the nitric solution of mercury, there are likewise others which depend on the state of this solution itself, and which it is of the utmost consequence to know, in order to avoid very considerable errors in the analysis of waters. Bergman has mentioned some of the remarkable differences observed in this solution, according to the manner in which it is made, either with or without heat, more particularly with respect to the colour of the precipitates it affords by different intermediums; but he does not say a word concerning the property this solution possesses, of being precipitated by distilled water, when it is highly charged with the oxyd of mercury; though Monnet mentions this fact in his treatise on the dissolution of metals. As this subject is of great importance in the analysis of waters, Fourcroy endeavoured by a very minute investigation to arrive at some degree of certainty concerning it, and has succeeded, as shall presently appear by very simple means. He has made a great number of solutions of mercury, in very pure nitric acid, with different doses of these two substances, with heat and in the cold, and with

acids of very different strengths. These experiments have afforded the following results:

1. Solutions made in the cold, became charged more or less readily with different quantities of mercury, according to the degree of concentration of the nitric acid: but whatever the quantity of mercury dissolved in the cold by the concentrated acid may be, no part of it will be precipitated by mere water. He dissolved in the cold two drachms and a half of mercury, in two drachms of nitrous acid red and fuming, weighing one ounce four drachms and five grains, in a bottle which contained an ounce of distilled water; the combination took place with the utmost rapidity; very dense nitrous gas escaped, together with aqueous vapours, dissipated by the heat of the mixture, amounting to more than one fourth of the acid. This solution was of a deep green, and very transparent: he poured a few drops into half an ounce of distilled water: some white striæ were formed, which were dissolved by agitation, and afforded no precipitate, though it was the most saturated solution he could make in the cold, and presented the greatest degree of commotion, effervescence, and red vapours, during the combination of the mercury and acids. As it had deposited crystals, he added two drachms of distilled water, which dissolved the whole without any appearance of precipitation. With much greater safety, therefore, may such solutions as have been made in the cold with common nitric acid, and half their weight of mercury, be used in the analysis of mineral waters, for they will never afford a precipitate by the addition of mere water.

2. The weakest nitric acid strongly heated on mercury, will dissolve a larger quantity than the strongest acid in the cold. The solution, which is thick and of a light yellow colour, will appear thick and oily, and will afford by standing, an irregular yellowish mass, which may be changed into a beautiful *turbith* by the addition of boiling water; this solution poured into distilled water, forms a very abundant precipitate of a yellow colour, similar to *turbith*. A solution made in the cold exhibits the same result, if it be strongly heated, so as to disengage a large quantity of nitrous gas. These solutions made with heat, ought therefore to be excluded from the analysis of mineral waters, because they are decomposable by distilled water.

3. The two solutions appear to differ from each other in the

quantity of oxyde of mercury, which is much greater in that which is precipitated by the water, than in that which is not decomposable by the fluid. M. Fourcroy has proved this, by evaporating equal quantities of both these solutions in an apothecary's phial, to reduce them into red precipitate, and he obtained one fourth more of this precipitate from the solution which is decomposed by water, than from that which is not rendered turbid. The specific gravity likewise appeared to be a good method of ascertaining the relative quantities of oxyd of mercury contained in these different fluids. He compared weights of equal masses of three mercurial nitrous solutions: the one, which was not at all precipitated by distilled water, and was the result of the first mentioned experiment, weighed one ounce one drachm and sixty-seven grains, in a bottle which contained exactly an ounce of distilled water. The second solution was made by a very gentle heat, and produced a slight opal colour with distilled water, and scarcely any sensible quantity of precipitate. The same bottle contained one ounce six drachms twenty-four grains. Lastly a third mercurial solution considerably heated, and which precipitated a true *turbith mineral* of a dirty yellow, by distilled water, weighed in the same bottle, one ounce seven drachms twenty-five grains. A decisive experiment remained to be made to confirm this opinion still more perfectly. If the solution precipitated by water, owed this property to a quantity of mercurial oxyd too large with respect to the acid, it would of course lose that property by the addition of acid; this accordingly happened. Aquafortis was poured on a solution which was decomposed by water, and it soon acquired the property of no longer being precipitated, and was absolutely in the same state as that which had been made slowly at first, by the mere heat of the atmosphere. Monnet has mentioned this process, as a means of preventing crystals of mercurial nitrat from becoming converted into oxyd by the contact of the air. It is by a contrary process, and by evaporating a portion of the acid of a good solution, which is not precipitated by water, that it is converted into a solution much more strongly charged with mercurial oxyd, and consequently capable of being decomposed by water; its original property may be restored by the addition of a quantity of acid, equal to that which it lost by evaporation.

Such are the different considerations M. Fourcroy has thought necessary to exhibit, that the effects of re-agents on waters may be better ascertained; but whatever may be the degree of precision to which researches of this nature may be carried; however extensive the knowledge we may have acquired concerning the degrees of purity, and the different states of such substances as are combined with mineral waters, for the purpose of discovering their principles, if it still remains a fact, that each of these re-agents is capable of indicating two or three different substances dissolved in these waters, the result of their action will always be subject to uncertainty. Lime, for example, seizes the carbonic acid, and precipitates salts with the base of alumine, and of magnesia, as well as the metallic salts. Ammoniac produces the same effect. Fixed alkalis, besides the above mentioned salts, precipitate those with base of lime. The calcareous prussiat, the prussiat of potash, and gallic alkohol, precipitate the sulphat and carbonat of iron. The nitric solutions of silver and of mercury, decompose all the sulphuric and muriatic salts, which may be various both in quantity and in kind, in the same water, and are themselves decomposable by alkalis, chalk, and magnesia. Among this great number of complicated effects, how shall we distinguish that which takes place in the water under examination, or by what means shall we ascertain whether it is simple or compounded?

These questions, though very difficult, for the time when the expedients of chemistry were little known, are nevertheless capable of being discussed in the present state of our knowledge. It must first be observed, that the nature of re-agents being much better known at present than it was some years ago, and their reaction on the principles of water better ascertained, it may, therefore, be strongly presumed that their application may be much more advantageously made than has hitherto been supposed; nevertheless, among the great number of excellent chemists who have attended to the analysis of waters, Messrs. Baumé, Bergman, and Gioanetti, are almost the only persons who have been aware of this great advantage. We have been long in the habit of examining mineral waters by re-agents, in very small doses, and often in glasses; the phenomena of the precipitations observed have been noted down, and the experiment carried no further. Baumé advises, in his chimistry, that a considerable quantity of the mineral water under examination,

should be saturated with fixed alkalis and with acids, that the precipitates be collected, and their nature examined. Bergman apprehended that the quantity of the principles contained in waters might be judged of from the weight of the precipitates obtained in these mixtures. Several other chemists have likewise employed this method, but always with a view to certain particular circumstances; and no one has hitherto proposed to make a connected analysis of mineral waters by this means. To succeed in this analysis, it would be proper to mix several pounds of the mineral water with each re-agent, till the latter ceases to produce any precipitate: the precipitate should then be suffered to subside during the time of twenty-four hours, in a vessel accurately closed; after which the mixture being filtered, and the precipitate dried and weighed, the operator may proceed to examine it by the known methods. In this manner the nature of the substance will be clearly ascertained, on which the re-agent has acted, and the cause of the decomposition may consequently be inferred. A certain order may be followed in these operations, by mixing the waters first with such substances as stand least capable of altering them, and afterwards passing to other substances capable of producing changes more varied and difficult to explain. The following method is that which Fourcroy commonly uses in this kind of analysis. After having examined the taste, the colour, the weight, and all the other physical properties of a mineral water, he pours four pounds of lime water on an equal quantity of the fluid; if no precipitate is made in twenty-four hours, he is sure that the water contains neither disengaged carbonic acid nor alkaline carbonat, nor earthy salts with the base of aluminous earth or magnesia, nor metallic salts. But if a precipitate be formed, he filters the mixture, and examines the chemical properties of the deposited substance; if it has no taste, if it be insoluble in water, or effervesces with acids, or forms an insipid and almost insoluble salt by the addition of sulphuric acid, he concludes that it is chalk, and that the lime water has acted only on the carbonic acid dissolved in the water. If, on the contrary, it is small in quantity, and subsides very slowly; if it do not effervesce, and affords with the sulphuric acid a styptic salt, or a bitter and very soluble salt, it is formed by magnesia or aluminous earth, and often by both.

After the examination by lime water, Fourcroy pours on four

other pounds of the same mineral water, a drachm or two of ammoniac perfectly caustic, or causes ammoniacal gas, disengaged by heat from the alkali, to pass into the water. When the water is saturated, it is left at rest in a close vessel for twenty-four hours; if a precipitate be afforded, it can only consist of ferruginous or magnesian, or aluminous salts, whose nature is examined by the different methods mentioned in the foregoing paragraph. But the action of ammoniacal gas being more fallacious than that of lime water, which produces the same decompositions, it must be observed that this last should only be used as an assistant means, which does not afford results equally accurate with those produced by the former re-agent.

When salts with base of aluminous earth, or magnesia, have been discovered by lime water, or by ammoniacal gas, the caustic fixed alkalis may be used, to distinguish those with base of lime, such as sulphat and muriat of lime. For this purpose Fourcroy precipitates some pounds of the water, which is examined by either of these liquid alkalis, till it no longer produces any turbidness. As this alkali decomposes salts with a base of aluminous earth, as well as those composed of lime; if the precipitate resembles in its form, colour, and quantity, that which lime water has afforded, it may be presumed that the water does not contain calcareous salt, and the chemical examinations of the precipitate usually confirms this suspicion: but if the mixture is much more turbid than that made with lime water; if the deposition be much heavier, more abundant, and more readily afforded, the lime is mixed with magnesia or alumine. This is ascertained by treating the precipitate after the different methods before explained. It may easily be concluded, that iron precipitated by re-agents, at the same time as the salino-terrestrial substances, is easily known by its colour and its taste; and that the small quantity of this metal separated in these processes, is not sufficient to effect the results.

It were useless to explain at large the effects of sulphuric acid, nitrous acid, gall-nuts, or of the calcareous and alkaline prussiats, employed as re-agents on mineral waters. The general account of these effects which has already been given may suffice; it need therefore only be noticed, that when they are mixed in large doses with these waters, and the precipitates collected, the nature and quantity of their principles may be more accurately ascertained, as

has been done by Messrs. Bergman and Gioanetti. The products which the nitric solutions of silver or mercury afford when mixed with mineral waters, deserve particular attention. It is more particularly necessary to operate with large quantities of water, when these re agents are used, in order to determine the nature of the acids contained in the waters. The analysis of these fluids will be complete when their acids are known, because these are often combined with the basis exhibited by the re-agents before-mentioned. The colours, the form, and the abundance of the precipitates afforded by the nitric solutions of mercury and silver, have hitherto exhibited to chemists the nature of the acids which caused them. A thick and ponderous deposition immediately formed by these solutions, denotes the muriatic acid: if it is small in quantity, white, and crystallized with the nitrat of silver, or yellowish, and yellow and irregular when formed with that of mercury, and if it subside but slowly, it is attributed to the sulphuric acid. But as these two acids are often met with in the same water, and as alkali and chalk likewise decompose the solutions, the results or deductions made from the physical properties of the precipitates must be uncertain. It is therefore necessary to examine them more effectually: for this purpose, solutions of silver or of mercury may be mixed with five or six pounds of the water intended to be analysed. The mixtures being filtered, twenty four hours after the precipitates must be dried, and treated according to the methods of chemistry. If the precipitate afforded by the nitric solution of mercury be heated in a retort, the portion of metal united with the muriatic acid of the waters will be volatilized into *mercurius dulcis*, and that which is combined with the sulphuric acid will remain at the bottom of the vessel, and exhibit a reddish colour. These two salts may likewise be distinguished by putting them on a hot coal; the sulphat of mercury, if present, emits a sulphureous acid, and assumes a red colour; the mercurial muriat remains white, and is volatilized without exhibiting any smell of sulphur. These phenomena likewise serve to distinguish the precipitates which may be formed by the alkaline substances contained in water, since the latter do not emit the sulphureous smell, and are not volatile without decomposition.

The precipitates produced by the combination of mineral waters with the nitric solution of silver, may be as easily examined

as the foregoing. Sulphat of silver being more soluble than the muriat of the same metal, distilled water may be successfully used to separate these salts. Muriat of silver is known by its fixity, its fusibility, and especially in its being less easily decomposed than sulphat of silver. This last, placed on hot coals, emits a sulphureous smell, and leaves an oxyd of silver, which may be fused without addition.

The Examination of the Mineral Waters by Distillation.—Distillation is used in the analysis of waters, to ascertain the gaseous substances they may be united to. These substances are either air, more or less pure, or carbonic acid, or sulphurated hydrogen gas. To ascertain their nature and quantity, some pounds of the mineral water must be poured into a retort, sufficiently large to contain it, without being filled more than half or two-thirds of its capacity; to this vessel a recurved tube is to be adapted, which passes beneath an inverted vessel filled with mercury. In this disposition of the apparatus, the retort must be heated till the water perfectly boils, or till no more elastic fluid passes over. When the operation is finished, the quantity of air contained in the empty space of the retort must be subtracted from the bulk of the gas obtained; the rest consists of aeriform fluid which was contained in the mineral water, whose properties may quickly be known by the proofs of a lighted taper, tincture of turnsole, and lime water; if it catches fire, and has a fœtid smell, it is sulphurated hydrogen gas; if it extinguishes the taper, reddens turnsole, and precipitates lime water, it is the carbonic acid; lastly, if it maintains combustion without taking fire, is without smell, and alters neither turnsole nor lime water, it is atmospheric air. It may happen that this fluid may be purer than the air of the atmosphere: in this case its degrees of purity may be judged by the manner in which it maintains combustion, or by mixing it with nitrous or hydrogen gas, in the eudiometers of Fontana and Volta. The process used in obtaining gaseous matters contained in waters is entirely modern. A moistened bladder was formerly used, which was adapted to the neck of a bottle filled with mineral water: the fluid was agitated, and by the swelling of the bladder, an estimate was made of the quantity of gas contained in the water. This method is now known to be fallacious, because water cannot give out all its gas but by ebullition, and because the

sides of the moistened bladder alter and decompose the elastic fluid obtained. It is scarcely necessary to remark, that the phenomena exhibited by the water, during the escape of the gas, must be carefully examined, and that a less quantity of water may be exposed to distillation, in proportion as its taste and sparkling indicate that it contains a larger quantity of gas.

Such is the method recommended by modern chemists to obtain the elastic fluids combined with waters: It must be observed, 1. That this process cannot be depended on, with regard to acidulous waters, unless the pressure of the atmosphere, and the state of compression of the elastic fluid under the glass vessels be more accurately accounted for: and as this is not easily done, the absorption of carbonic acid by lime water, proposed by Gioanetti, appears to be preferable. 2. Though it has been recommended by Bergman to obtain sulphurated hydrogen gas from sulphureous waters, it does not answer, because the heat of ebullition decomposes the gas, and it is likewise decomposed by the mercury, which is converted into ethiops, as soon as it comes in contact with this elastic fluid: for this reason, litharge should be used to absorb this gas in the cold, and to deprive sulphureous waters of their sulphur.

The Examination of Mineral Waters by Evaporation.— Evaporation is generally considered as the most certain method of obtaining all the principles of mineral waters. We have before observed, and here repeat, from various well conducted experiments, that long continued ebullition may decompose saline matters dissolved in water, and for that reason we have advised the examination of them by re-agents, employed in greater proportions; yet evaporation may afford much information, when used, together with the analysis by re-agents, which ought always to be considered as one of the principal methods of examining waters.

The intention of evaporation being to collect the fixed principles contained in a mineral water, it is obvious, that in order to know the nature and proportion of these principles, a considerable quantity of the water must be evaporated, and so much the more, in proportion as the principles appear to exist in smaller quantities. When the water is thought to contain a large quantity of saline matter, about twenty pounds must be evaporated; if, on the contrary, it appears to hold but a very small quantity in solution, it will be necessary to evaporate a much larger quantity. It is sometimes re-

quisite to perform this operation with several hundred pounds. The nature and form of the vessels in which waters are exposed for evaporation, is not a matter of indifference: those of metal, excepting silver, are altered by water; vessels of glass, of a certain magnitude, are very subject to be broken; but those of glazed smooth pottery are the most convenient, though the cracks in the glaze sometimes cause an absorption of saline matter; vessels of unglazed porcelain, called biscuit, would doubtless be the most convenient, but their price is a considerable obstacle. Chemists have proposed different methods of evaporating mineral waters; some have directed distillation to dryness, in close vessels, in order to prevent foreign substances, which float in the atmosphere, from mixing with the residue; but this method is excessively tedious: others have advised evaporation by a gentle heat, never carried to ebullition, because they supposed that this last heat alters the fixed principles, and carries up a portion of them. This was the opinion of Venal and Bergman. Monnet, on the contrary, directs the water to be boiled, because this motion prevents the reception of foreign matters contained in the atmosphere. Bergman avoids this inconvenience, by directing the vessel to be covered, and a hole left in the middle of the cover for the vapours to pass out: this last method greatly retards the evaporation, because it diminishes the surface of the fluid. At the commencement, the heat used must be sufficient to repel the dust; but the greatest difference in the manipulation of this experiment consists in some writers directing that the substances deposited should be separated, as the evaporation proceeds, in order to obtain each pure and by itself; others, on the contrary, direct the operation to be carried on to dryness. We are of the opinion of Bergman, that this last method is the most expeditious and certain; because, notwithstanding the care which may be taken, in the first method, to separate the different substances which are deposited or crystallized, they are never obtained pure, and must always be examined by a subsequent analysis; and the method is besides inaccurate, on account of the frequent filtrations, and the loss it occasions. Lastly, it is very embarrassing, and renders the evaporation much longer. Mineral waters may therefore be evaporated to dryness, in open glass vessels, on the water-bath, or still more advantageously in glass retorts, on a sand-bath.

Various phenomena are observed during this operation; if the

water be acidulous, it emits bubbles, as soon as the heat first begins to act; in proportion as the carbonic acid is disengaged, a pellicle is formed, with a deposition of calcareous earth, and carbonat of iron. These first pellicles are succeeded by the crystallization of sulphat of lime; and lastly, the muriats of potash and soda crystallize in tubes at the surface, but the deliquescent salts are not obtained but by evaporation to dryness.

The residue must then be weighed, and put into a small phial, with three or four times its weight of alkohol: the whole being agitated, and suffered to subside for some hours, must be filtrated, and the alkohol preserved separate. The residue on which the spirit has not acted, must be dried in a gentle heat, or in the open air; when perfectly dry it must be weighed, and the loss of weight will show what quantity of calcareous or magnesian muriat was contained, because these salts are very soluble in alkohol. We shall presently speak of the method of ascertaining the presence of these two salts in the spirituous fluid.

The residue, after treatment with alkohol, and drying, must be agitated with eight times its weight of cold distilled water, and filtered. After some hours standing, the residue is to be dried a second time, and boiled half an hour in four or five hundred times its weight of distilled water; this last residue, after filtration, consists of that which cold or boiling water is insufficient to dissolve. The first water contains neutral salts, such as sulphat of soda, or of magnesia; the muriat of soda, or potash and the fixed alkalis, especially soda united with carbonic acid: the large quantity of boiling water scarcely contains any substance but sulphat of lime. There are therefore four substances to be examined, after these different operations on the matter obtained by evaporation. 1. The residue insoluble in alkohol, and in water of different temperatures. 2. The salts dissolved in alkohol. 3. The salts dissolved in cold water. 4, and lastly, Those dissolved in boiling water. We shall now proceed to the experiments necessary to ascertain the nature of these different substances.

1. The residue which has resisted the action of the alkohol and water, may be composed of calcareous earth, of carbonat of magnesia and iron, of alumine, and of quartz. These two last substances are seldom found in waters, but the three first are very common; brown, or more or less deep yellow colour, indicates the presence

of iron. If the residue be of a white grey, it does not contain this metal. When iron is present, Bergman directs it to be moistened, and exposed to the air till it rusts; in which state vinegar does not act on it. In order to explain the methods of separating these different substances, we will suppose an insoluble residue to consist of the five substances here mentioned; it must first be moistened, and exposed to the rays of the sun; and when the iron is perfectly rusted, the residue must be digested in distilled vinegar. This acid dissolves the lime and magnesia, and by evaporation affords the calcareous acetit, distinguishable from the acetit of magnesia, by its not attracting the humidity of the air. They may consequently be separated by deliquescence, or by pouring sulphuric acid into their solution. The latter forms sulphat of lime, which precipitates; but if the magnesian acetit be present, the sulphat of magnesia, composed of magnesia united with the sulphuric acid, will remain in solution, and may be contained by a well-conducted evaporation. To ascertain the quantity of magnesia and calcareous earths contained in this residue, sulphat of lime is first to be precipitated: and the sulphat of magnesia, formed by the sulphuric acid poured into the acetous solution, must then be precipitated by carbonat of potash. the quantities of these precipitates are known by weighing. When the chalk and magnesia of the residue are thus separated, the iron, the alumine, and the quartz remain. The iron and the alumine are dissolved by pure muriatic acid, from which the former is precipitated from prussiat of lime, and the latter by carbonat of potash. These precipitates must likewise be weighed. The matter which remains after the separation of the alumine and iron is usually quartzose; its quantity may be known by weighing, and its habitudes by fusion of the blow-pipe with carbonat of soda. Such are the most accurate processes, recommended by Bergman, for examining the insoluble residue of waters.

2. The alkohol used in washing the solid residue of mineral waters, must be evaporated to dryness. Bergman advises treating it with sulphuric acid diluted with water in the same manner as the acetous solution before spoken of; but it must be observed, that this process serves only to exhibit the bases of these salts. To determine the acid, which is ordinarily united with magnesia or lime, and sometimes with both, a few drops of concentrated sulphuric acid must be poured on, which excites an effervescence, and disen-

gages the muriatic gas, known by its smell and white vapour, when the salt under examination contains that acid. This may likewise be known by dissolving the whole residue in water, and adding a few drops of the nitric solution of silver. The nature of the base, which, as we have observed, is either lime, magnesia, or both together, is known by the name of the sulphuric acid, by a similar process with that already explained respecting the acetous solution.

3. The water used in washing the first residue of the mineral water, performed, as before directed, with eight times its weight of cold distilled water, contains neutral alkaline salts, such as sulphat of soda, muriats, or marine salts, carbonat of potash, and of soda, and sulphat of magnesia: a small quantity of sulphat of iron is sometimes found. These salts never exist altogether in waters: the sulphat of soda, and the carbonat of potash, are very seldom found; but marine salt is frequently met with, together with carbonat of soda. The sulphat of magnesia is likewise frequently met with, and some waters even contain it in considerable quantities. When the first washing of the residue of a mineral water contains only one kind of neutral salt, it may easily be obtained by crystallization, and its nature ascertained from its form, taste, and the action of fire, as well as that of the re-agents: but this case is very rare, for it is much more usual to find many salts united in this lixivium. They must therefore be separated, if practicable, by slow evaporation; but as this method does not always perfectly succeed, however carefully this evaporation be conducted, it will be necessary to re-examine the salts obtained at the different periods of the evaporation. Carbonat of soda is usually deposited confusedly with the muriatic salts, but they may be separated by a process, pointed out by M. Gioanetti. It consists in washing this mixed salt with distilled vinegar; for this acid dissolves the carbonat of soda. The mixture must then be dried and washed a second time with alkohol, which takes up the acetit of soda, without acting on marine salt. The spirituous solution being evaporated to dryness, and the residue calcined, the vinegar becomes decomposed and burns. Soda alone remains, whose quantity may be then accurately determined.

4. The water used in the quantity of four or five hundred times the weight of the residuum of the mineral water contains only sulphat of lime. This may be ascertained by pure caustic ammoniac,

which occasions no change, while caustic potash precipitates it abundantly. By evaporation to dryness, the quantity of earthy salt contained in the water may be accurately ascertained.

Concerning artificial Mineral Waters.—The numerous processes we have prescribed for examining the residues of mineral waters by evaporation, serve to ascertain, with the greatest precision, all the several matters held in solution in these fluids. Another process remains to be made to prove the success of the analysis, viz. That of imitating nature in the way of synthesis, by dissolving in pure water the different substances obtained by the analysis of mineral water which has been examined. If the artificial mineral water has the same taste, the same weight, and exhibits the same phenomena with re-agents as the natural mineral water, it is the most complete, and the most certain proof that the analysis has been well made. This artificial combination has likewise the advantage of being procured in all places at pleasure, and at a trifling expence; and is even in some cases superior to the natural mineral waters, for their whole properties may be changed by carriage and other circumstances. The most celebrated chemists are of opinion, that it is possible to imitate mineral waters. Macquer has observed, that since the discovery of the carbonic acid, and the property it is found to possess of rendering many substances soluble in water, it is much more easy to prepare artificial mineral waters. Bergman has described the method of composing waters which perfectly imitate that of Spa, Seltzer, Pyrmont, &c. He likewise informs us, that they are used with great success in Sweden, and that he himself has experienced their good effects. Duchanoy has published a work, in which he has given a number of processes for imitating all the mineral waters usually employed in medicine. We may therefore hope, that chemistry may render the most essential service to the art of healing, by affording valuable medicines, whose activity may be increased or diminished at pleasure.

In order to present the reader, under one point of view, with the most conspicuous features in the composition of the mineral waters of this and some other countries, the following Synoptical Table is subjoined, from Dr. Saunders' work on mineral waters.

The reader will please to observe, that under the head of *Neutral Purging Salts*, are included the sulphats of soda and magnesia, and

the muriats of lime, soda, and magnesia. The power which the earthy muriats possess of acting on the intestinal canal, is not quite ascertained, but from their great solubility, and from analogy with salts, with similar component parts, we may conclude that this forms a principal part of their operation.

The reader will likewise observe, that where the spaces are left blank, it signifies that we are ignorant whether any of the substance at the head of the column is contained in the water; that the word *none* implies a certainty of the absence of that substance; and the term *uncertain*, means that the substance is contained, but that the quantity is not known.

A SYNOPTICAL TABLE, shewing the composition of MINERAL WATERS.

CLASS.	NAME.	Highest Temperature.	Azotic Gas.	Carbonic Acid Gas.	Sulphurated Hydrogen.	Carbonated Soda.	Neutral Purging Salts.	Selenite and Earthy Carbonates.	Oxyd of Iron.
			Contained in an English Wine Pint of 28.875 Cubic Inches.						
		Fahrenheit.	Cubic Inches.	Cubic Inches.	Cubic Inches.	Grains.	Grains.	Grains.	Grains.
Simpler cold	Malvern			uncertain	none	none	uncertain	uncertain	none
	Holywell			–	none	none	uncertain	uncertain	none
Simpler thermal	Bristol	74°	uncertain	3.75	none	none	2.81	3.16	none
	Matlock	66°		uncertain	none	none	uncersain	uncertain	none
	Buxton	82°	0.474	uncertain	none	none	0.25	1.625	none
Simple saline	Sedlitz			1.	none	none	185.6	8.68	none
	Epsom				none	none	40. ?	8. ?	none
	Sea				none	none	237.5	6.	none
Highly carbonated alkaline	Seltzer			17.	none	4.	17.5	8.	none
Simple carbonated chalybeate	Tunbridge		0.675	1.325	none	none	0.344	0.156	0.125
Hot carbonated chalybeate	Bath	116°	1. ?	1. ?	none	none	10. ?	10. ?	uncertain
Highly carbonated chalybeate	Spa			12.79	none	1.47	4.632	1.47	0.56
	Pyrmont			26.	none	none	7.13	23.075	0.56
Saline, carbonated chalybeate	Cheltenham		uncertain	5.687	uncertain	none	62.125	6.85	0,625
	Scarborough			uncertain	none	none	20.	10.	uncertain
Hot, saline, highly carbonated chalybeate	Vichy	120° ?		uncertain	none	uncertain		uncertain	uncertain
	Carlsbad	165°		uncertain	none	11.76	47.04	4.15	uncertain
Vitriolated chalybeate	Hartfell				none	none	none	none	4.815 *
Cold sulphureous	Harrowgate		0.875	1.	2.375	none	91.25	3.	none
	Moffat		0.5	0.625	1.25	none	4.5	none	none
Hot alkaline sulphureous	Aix	143°		uncertain	uncertain	12.	5.	4.75	none
	Borset	132°		uncertain	uncertain	uncertain	uncertain		none
	Berege	120°			uncertain	2.5	0.5	uncertain	none

* That is, 2.94 contained in the sulphat of iron, (this salt, when crystallized, containing 28 per cent. of oxyd of iron, according to Kirwan) and 1.875 additional of oxyd of iron.

SECTION IX.

Cataracts and Inundations.

1. *Cataracts of the Nile.*

THE bed and course of this river we have described in a previous chapter. Through its long and fertile range of about two thousand British miles, it has often to wind through abrupt and precipitous countries; and is not unfrequently strengthened by other rivers, as well as occasonal lakes and rapids. In consequence of which it often exhibits very considerable cataracts or water-falls. With respect to the number of these the different travellers are not agreed, some having placed in the catalogue, several of not more than seven or eight feet of perpendicular height, which others have rejected as too diminutive to deserve notice. We may safely affirm, however, that it contains not less than ten or twelve whose descent may be estimated at upwards of twenty feet before it reaches the level of Egypt. One of the chief occurs to the north-east of Morcho, where the Nile, having traversed a long and rugged chain of mountains, throws itself down to a considerable depth in a wide precipitous sheet, and forms the cataract of Jan Adel at Janadil, constituting the seventh fall in its regular course. But that which, by way of eminence, is called *the Cataract of the Nile*, occurs in a different country and a very different part of the river, at the village of Atalata, near Dara. It constitutes the eighth cataract, and is thus described by Mr. Bruce :

Our horses were immediately fed ; bread, honey, and butter served : Ali had no occasion to cry, Drink ; it went about plentifully, and I would stay no longer, but mounted my horse, thinking every minute that I tarried might be better spent at the cataract. The first thing they carried us to was the bridge, which consists of one arch, of about twenty-five feet broad, the extremities of which were strongly let into, and rested on, the solid rock on both sides ; but fragments of the parapets remained, and the bridge itself seemed to bear the appearance of frequent repairs, and many attempts to ruin it ; otherwise, in its construction, it was exceedingly commodious. The Nile here is confined between two rocks, and runs in a deep trough, with great roaring and impetuous velocity. We were told no crocodiles were ever seen so high, and were obliged to remount the stream above half a mile before we came to the cataract,

through trees and bushes of the same beautiful and delightful appearance with those we had seen near Dara.

The cataract itself was the most magnificent sight that ever I beheld. The height has been rather exaggerated. The missionaries say, the fall is about sixteen ells, or fifty feet. The measuring is, indeed, very difficult; but, by the position of long sticks, and poles of different lengths, at different heights of the rock, from the water's edge, I may venture to say, that it is nearer forty feet than any other measure. The river had been considerably increased by rains, and fell in one sheet of water, without any interval, above half an English mile in breadth, with a force and noise that was truly terrible, and which stunned me, for a time, perfectly dizzy. A thick fume, or haze, covered the fall all round, and hung over the course of the stream both above and below, marking its track, though the water was not seen. The river, though swelled with rain, preserved its natural clearness, and fell, as far as I discern, into a deep pool, or bason, in the solid rock, which was full, and in twenty different eddies to the very foot of the precipice; the stream, when it fell, seeming part of it to run back with great fury upon the rock, as well as forward in the line of its course, raising a wave, or violent ebullition, by chaffing against each other.

Jerome Lobo pretends, that he has sat under the curve, or arch, made by the projectile force of the water rushing over the precipice. He says he sat calmly at the foot of it, and looking through the curve of the stream, as it was falling, saw a number of rainbows of inconceivable beauty in this extraordinary prism. This, however, I, without hesitation, aver to be a downright falsehood. A deep pool of water, as I mentioned, reaches to the very foot of the rock, and is in perpetual agitation. Now, allowing that there was a seat, or bench, which there is not, in the middle of the pool, I do believe it absolutely impossible, by any exertion of human strength, to have arrived at it. Although a very robust man, in the prime and vigour of life, and a hardy, practised, indefatigable swimmer, I am perfectly confident I could not have got to that seat from the shore through the quietest part of that bason. And, supposing the friar placed in his imaginary seat, under the curve of that immense arch of water, he must have had a portion of firmness, more than falls to the share of ordinary men, and which is not likely to be acquired in a monastic life, to philosophise upon optics in such a situation, where every thing would seem, to his dazzled eyes, to be in motion, and

FALLS OF THE NIAGARA, IN CANADA.

the stream, in a noise like the loudest thunder, to make the solid rock (at least as to sense) shake to its very foundation, and threaten to tear every nerve to pieces, and to deprive one of other senses besides that of hearing. It was a most magnificent sight, that ages, added to the greatest length of human life, would not efface or eradicate from my memory; it struck me with a kind of stupor, and a total oblivion of where I was, and of every other sublunary concern. It was one of the most magnificent, stupendous sights in the creation, though degraded and vilified by the lies of a grovelling fanatic priest.

I was awakened from one of the most profound reveries that ever I fell into, by Mahomet, and by my friend Drink, who now put to me a thousand impertinent questions. It was after this I measured the fall, and believe, within a few feet, it was the height I have mentioned; but I confess I could at no time in my life less promise upon precision; my reflection was suspended, or subdued; and, while in sight of the fall, I think I was under a temporary alienation of mind; it seemed to me as if one element had broke loose from, and become superior to, all laws of subordination; that the fountains of the great deep were again extraordinarily opened, and the destruction of a world was once more begun by the agency of water.

[*Bruce's Travels, Vol. V.* 8vo.

2. *Falls of the River Niagara, drawn up from M. Borassaw's Account. By the Hon. Paul Dudley, F.R.S.*

The falls of Niagara are formed by a vast ledge or precipice of solid rock, lying across the whole breadth of the river, a little before it empties itself into, or forms the lake Ontario.

M. Borassaw says, that in spring 1722, the governor of Canada ordered his own son, with three other officers, to survey the Niagara, and take the exact height of the cataract, which they accordingly did with a stone of half a hundred weight, and a large cod-line, and found it on a perpendicular no more than 26 fathoms, *vingt et six brass.*

This differs very much from the account Father Hennepin has given of that cataract; for he makes it 100 fathoms, and our modern maps from him, as I suppose, mark it at 600 feet; but I believe Hennepin never measured it, and there is no guessing at such things.

When I objected Hennepin's account of those falls to M. Borassaw, he replied, that accordingly every body had depended on it as right, until the late survey. On further discourse he acknowledged, that below the cataract, for a great way, there were numbers of small ledges or stairs across the river, that lowered it still more and more, till you come to a level; so that if all the descents be put together, he does not know but the difference of the water above the falls and the level below, may come up to father Hennepin; but the strict and proper cataract on a perpendicular is no more than 26 fathoms, or 156 feet, which yet is a prodigious thing, and what the world I suppose cannot parallel, considering the size of the river, being near a quarter of an English mile broad, and very deep water.

Several other things M. Borassaw set me right in, as to the falls of the Niagara. Particularly it has been said, that the cataract makes such a prodigious noise, that people cannot hear each other speak at some miles distances; whereas he affirms, that you may converse together close by it. I have also heard it positively asserted, that the shoot of the river, when it comes to the precipice, was with such force, that men and horse might march under the body of the river without being whet; this also he utterly denies, and says, the water falls in a manner right down.

What he observed farther to me was, that the mist or shower which the falls make, is so extraordinary, as to be seen at five leagues distance, and rises as high as the common clouds. In this brume or cloud, when the sun shines, you have always a glorious rainbow. That the river itself, which is there called the river Niagara, is much narrower at the falls than either above or below; and that from below there is no coming nearer the falls by water than about six English miles, the torrent is so rapid, and having such terrible whirlpools.

He confirms Father Hennepin's and Mr. Kelug's account of the large trouts of those lakes, and solemnly affirmed there was one taken lately, that weighed 86 lb. which I am the rather inclined to believe, on the general rule, that fish are according to the waters. To confirm which, a very worthy minister affirmed, that he saw a pike taken in Canada river, and carried on a pole between two men, that measured five feet ten inches in length, and proportionably thick.

I myself saw a cataract, three leagues above Albany, in the province of New York, on Schenectada river, called the Cohoes, which they count much of there, and yet it is not above 40 or 50 feet perpendicular. From these falls also there rises a misty cloud, which descends like small rain, which, when the sun shines gives a handsome small rainbow, that moves as you move, according to the angle of vision. The river at the Cohoes is 40 or 50 rods broad, but then it is very shallow water, for in a dry season the whole river runs in a channel of not more than 15 feet wide.

In my journey to Albany, 20 miles to the eastward of Hudson's river, near the middle of a long rising hill, I met with a brisk noisy brook, sufficient to serve a water-mill; and having observed nothing of it at the beginning of the hill, I turned about, and followed the coarse of the brook, till at length I found it come to an end, being absorbed, and sinking into the ground, thence either passing through subterraneous passages, or soaked up by the sand; and though it be common in other parts of the world for brooks and even rivers thus to be lost, yet this is the first of the sort I have heard of, or met with, in this country.

[*Phil. Trans.* 1722.

The Fall of Fyers.

THE fall of Fyers, is a vast cataract, in a darksome glen of a stupendous depth; the water darts far beneath the top through a narrow gap between two rocks, then precipitates above forty feet lower into the bottom of the chasm, and the foam, like a great cloud of smoke, rises and fills the air. The sides of this glen are vast precipices mixed with trees over-hanging the water, through which, after a short space, the waters discharge themselves into the lake.

About half a mile south of the first fall is another passing through a narrow chasm, whose sides it has undermined for a considerable way: over the gap is a true Alpine bridge of the bodies of trees covered with sods, from whose middle is an aweful view of the water roaring beneath.

At the fall of Foher the road quits the side of the lake, and is carried for some space through a small vale on the side of the river Fyers, where is a mixture of small plains of corn and rocky hills.

Then succeeds a long and dreary moor, a tedious ascent up the mountain See-chuimin or Cummin's seat, whose summit is of a great height and very craggy. Descend a steep road, leave on the right Loch-Taarf, a small irregular piece of water, decked with little woody isles, and abounding with Char. After a second steep descent, reach Fort Augustus *, a small fortress, seated on a plain at the head of Loch-Ness, between the rivers Taarf and Oich; the last is considerable, and has over it a bridge of three arches. The fort consists of four bastions; within is the governor's house, and barracks for 400 men: it was taken by the rebels in 1746, who immediately deserted it, after demolishing what they could.

Lock-Ness is twenty-two miles in length; the breadth from one to two miles, except near Castle Urquhart, where it swells out to three. The depth is very great; opposite to the rock called the *Horse-shoe*, near the west end, it has been found to be 140 fathoms. From an eminence near the fort is a full view of its whole extent, for it is perfectly strait, running from east to west, with a point to the south. The boundary from the fall of Fyres is very steep and rocky, which obliged General Wade to make that *detour* from its banks, part on account of the expense in cutting through so much solid rock, partly through an apprehension that in case of a rebellion the troops might be destroyed in their march, by the tumbling down of stones by the enemy from above: besides this, a prodigious arch must have been flung over the Glen of Fyers.

This lake, by reason of its great depth, never freezes, and during cold weather a violent steam rises from it as from a furnace. Ice brought from other parts, and put into Loch-Ness, instantly thaws; but no water freezes sooner than that of the lake when brought into a house. Its water is esteemed very salubrious; so that people come or send thirty miles for it: old Lord Lovat in particular made constant use of it. But it is certain, whether it be owing to the water, or to the air of that neighbourhood, that for seven years the garrison of Fort Augustus had not lost a single man.

The fish of this lake are salmon, which are in season from Christmas to Midsummer, trouts of about 2lb. weight, pikes and eels. During winter it is frequented by swans and other wild fowls.

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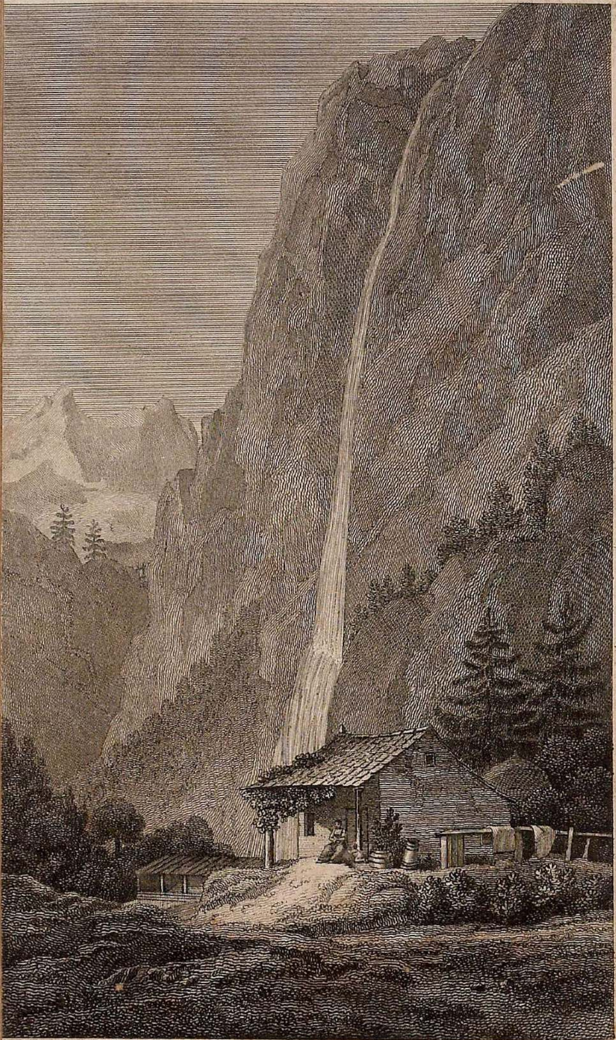
* Its Erse name is *Kil-chuimin*, or the burial-place of the Cummins. It lies on the road to the isle of Skie, which is about 52 miles off; but on the whole way there is not a place fit for the reception of man or horse.



graved by Angus, from a Drawing by Craig — for the Gallery of Nature & Art

FALL OF THE STAUB - BACH

in the Valley of Lauterbrunnen: computed at 900. ft. perpendicular height.

London. Published by R. Wilks, 89, Chancery Lane. Mar. 1, 1814.

The greatest rise of water in Loch-Ness is fourteen feet. The lakes from whence it receives its supplies are Loch-Oich, Loch-Garrie, and Loch-Quich. There is but very little navigation on it; the only vessel is a gally belonging to the fort, to bring the stores from the east end, the river Ness being too shallow for navigation.

It is violently agitated by the winds, and at times the waves are quite mountainous. November 1, 1755, at the same time as the earthquake at Lisbon, these waters were affected in a very extraordinary manner: they rose and flowed up the lake from east to west with vast impetuosity, and were carried above 200 yards up the river Oich, breaking on its banks in a wave near three feet high; then continued ebbing and flowing for the space of an hour: but at eleven o'clock a wave greater than any of the rest came up the river, broke on the north side, and overflowed the bank for the extent of 30 feet. A boat near the General's Hut, loaden with brush-wood, was thrice driven ashore, and twice carried back again; but the last time, the rudder was broken, the wood forced out, and the boat filled with water and left on shore. At the same time, a little isle, in a small loch in Badenoch, was totally reversed and flung on the beach. But at both these places no agitation was felt on land.

[*Pennant's Tour in Scotland.*]

4. *Brief Survey of other remarkable Cataracts.*

THE bold and precipitous country of the Alps offers us a variety of waterfalls and perpendicular torrents that are well worthy of notice; and especially those about Mount Rosa, a northern boundary of Piedmont, and probably the Mons Sylvius of the ancients. Thus the river Oreo, fed by numerous streams from St. Gothard, Mount Cenis, and some branches of the Appennines, forms at Ceresoli a vertical cascade computed at 400 fathoms, or 2,400 feet: while the torrent Evanson, descending from another part of Mount Rosa, exhibits, about half a mile from Vernez, a fall of more than 200 fathoms, and rolls down pebbles of quartz, veined with the gold that is occasionally traced in the mountains of Challand.

The *Cascata del Marmore*, or *Marble Cascade*, so denominated from the mountain down which the Velcino falls, being almost wholly of marble, lies about three miles from Terni, and the road to it, part of which is cut in the rock in the side of the mountain,

is without rails, and very slippery, and consequently very dangerous to men and horses. The traveller is struck with terror on viewing the precipices, which are of romantic height; but is sufficiently rewarded, when, on reaching the top of the mountain, he views the stupendous cataract formed by the Velcino as it rushes from the mountain.

The river, after running some miles with a gentle course, reaches the declivity of its channel, which is shaded with many massy trees, covered with perpetual verdure, as are the mountains by which it is surrounded The waters afterward descend with a rapid course for a short space, and then fall from a perpendicular height of three hundred feet, breaking against lateral rocks, which cause vapours to ascend much higher than the summit of the cataract, by which the neighbouring valley receives a perpetual fall of rain. After this descent, the waters rush into the cavities of the rocks, and then bursting through several openings, at length arrive at the bed of the river.

In Savoy, the Arvo runs for many miles between high, craggy, and inaccessible rocks, which seem as if split on purpose to give its rapid waters a free passage. The surprising echoes and continual sounds occasioned by its streams, the trampling of the horses and mules, the hallowing of passengers, &c. in those places, are reverberated three, four, and even in some parts six or seven times, with a noise so deep and wild, as to strike the traveller, unaccustomed to them, with terror; and the firing of a gun or pistol, is here more terrible than the loudest claps of thunder. The roads which are cut along the sides of the steep, and in many places are not above five or six feet wide, afford, both above and below, the dreadful prospect of a steep precipice, with impending, monstrous rocks, that seem just ready to fall; which, joined to the roaring of the river, adds largely to the general sublimity. The cataracts of this river in several places are more or less loud and terrible, according as the waters are more or less swelled by the melting snows, with which the tops of the mountains are covered. One in particular, called by the inhabitants the *Nun of Arpena*, falls from a prodigious high rock with great noise and violence; and its fall is said to be above eleven hundred feet. Over this river, travellers are obliged to pass seven or eight times by bridges, some of

which are very strong and beautiful, and others so old and crazy, that it is almost impossible to cross them without danger.

On the north-eastern coast of the Adriatic Sea, in Dalmatia, the river Cettina forms a magnificent cascade, called by the natives *Velica Gubaviza*, to distinguish it from a less fall a little below. The Abbé Fortis is almost the only traveller who speaks of this natural curiosity, and to enable himself to do it he was obliged to creep, and sometimes to leap from one rock to another, in order to arrive at the station where he could obtain a full view of it. Notwithstanding the difficulty of access, here, he says, the shepherds, with their leathern flasks full of water, climb with surprising dexterity from the bottom of the abysses to the level tops of the hills, where their thirsty flocks feed. If any of them miss a step, they must inevitably fall, and become food for the vultures; but such accidents rarely happen. The waters precipitate themselves from a height of above one hundred and fifty feet, forming a deep majestic sound, which is heightened by the echo resounding between the steep and naked marble banks. Many broken fragments of rocks, which impede the course of the river after its fall, break the waves, and render them still more lofty and sounding; their froth, by the violence of the repercussion, flies off in small white particles, and is raised in successive clouds, which, by the agitated air, are scattered over the moist valley, where the rays of the sun seldom penetrate to rarefy them. When these clouds ascend directly upward, the inhabitants expect the noxious south-east wind, which the Abbé styles "the sciocco," and their presage seldom fails. Two huge pilasters stand, as if for a guard, where the river takes its fall; one of which is joined to the craggy brink, having its top covered with earth, and adorned with trees and grass; the other is of marble, bare and insulated.

About a league from Schaffhausen, at Lauffen, in Swisserland, is a tremendous cataract on the Rhine, where the river precipitates itself from a rock said to be seventy feet high, and ninety paces in breadth.

Near the city of Gottenburgh, or Gotheburg, in Sweden, the river Gotha rushes down from a prodigious high precipice into a deep pit, with a terrible noise, and such vast force, that the trees designed for the masts of ships, which are floated down the river, are usually turned upside down in their fall, and are frequently

shattered to pieces. They frequently dive so far under water, as to disappear for a quarter of an hour, half an hour, and sometimes three quarters of an hour. The pit into which the torrent precipitates them, is of a depth not to be ascertained, having been sounded with a line of several hundred fathoms, without reaching the bottom *.

In Norway, from the multitude of springs that issue from its lofty mountains, and the vast masses of snow accumulated on their summits, which gently dissolve in summer, are formed many lakes, in some of which are floating islands, and a considerable number of rivers, the largest of which is the Glommen or Glamer; but none of them are navigable far up the country, the passage being every where interrupted by rocks, and in some places by dreadful cataracts, in which the stream precipitates itself from the height of forty, fifty, and even a hundred fathoms. The bridges over these rivers are not walled, but formed of timber cases filled with stones, which serve for the piers on which the wooden-work is laid. The largest bridge of this kind has forty-three stone cases, and is a hundred paces in length. In those places where the narrowness and rapidity of the current will not admit of sinking such cases, thick masts are laid on each side of the shores, with the largest end fastened to the rocks; one mast being thus laid in the water, another is placed upon it, reaching a fathom beyond it, and then a third or fourth in like manner to the middle of the stream, where it is joined by other connected masts from the opposite side. Thus in passing over the bridge, especially in the middle, it seems to swing, which, to those who are not used to such contrivances, appears extremely dangerous; so that, filled with terror, passengers alight from their horses, and lead them over.

In England, in the county of Devon, the Tamar receives a small river called the Lid, which is peculiarly remarkable for being pent up with rocks at the bridge, and running so far below it, that the water is scarcely to be seen, or the murmurs of it to be heard, to the astonishment of all strangers who have the curiosity to attend to these uncommon circumstances; for the bridge is level with the road, and the water runs nearly seventy feet below it.

Within a mile of this place is a cataract, where the water falls

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* See Mr. Gordon's account of this curious waterfall, Ph. Trans. for 1700.

above a hundred feet; it comes from a mill at some distance, and after a course upon a descent of near an hundred feet from the level of the mill, it arrives at the brink of the precipice, whence it falls in a beautiful manner, and striking upon a part of the cliff, rushes from it in a wider cataract to the bottom, where falling with great violence, it makes a deep and foaming bason in the ground. This wonderful fall of water causes the surrounding air at the bottom to be so impregnated with aqueous particles, that a person approaching it finds himself in a mist.

In the vale of Kingsdale, on the western extremity of Yorkshire, is Yordas cave, which presents a subterraneous cascade; this cave is about fifty yards in length. But the most noted is Wethercot cave, not far from Ingleton. It is surrounded with trees and shrubs, in form like a lozenge, divided by an arch of lime-stone, passing under which you behold a large cascade, falling from a height of more than twenty yards; the length of this cave is about sixty yards, the breadth thirty. This large limestone base of Ingleborough is perforated in all directions like a honeycomb. It is the river Wease, or Greta, which pervades the cave at Wethercot, and another at Gatekirk, and runs not less than two miles under-ground. This stream must not be confounded with the Greta, which falls into the Tees near Barnard-castle, and rises near Brough, in Stanmore; two rivers, the Ouse and the Swale, running betwixt them. Among other curiosities in this neighbourhood, must not be omitted Hurtlepot, a round deep cavity, near forty yards in diameter, almost surrounded with rocks, about thirty feet perpendicular, above its black waters, while the overbranching trees increase the horrors of the scene. Not far to the south-east, is a lake called Malham Tarn, of clear and very cold water, abounding in trout. This is the source of the river Aire, which runs about a mile under-ground; and near it is Malham cove, a kind of amphitheatre, of smooth perpendicular limestone, about 280 feet high in the centre. The river Ribble, near its origin in these parts, also sinks into a deep cavern; and silently pervades the mountains for about three miles. Near Settle, at the bottom of some calcareous rocks, is one of the most remarkable ebbing and flowing wells in the kingdom.

Mr. Housman also gives a good account of these curiosities, he observes, p. 26, that rocks are in Cumberland called *Linns*,

(whence the name is in Scotland applied to a cataract); and Sour Milk Force, near the bottom of Buttermere lake, is supposed to fall upwards of 300 yards. A curious cave was lately discovered, p. 83, by miners near Crossfell, said to be two miles in length, and full of splendid spars. Gordale Scarr, p. 199, near Malham cove, is a dreadful rent through high rocks, worthy of the attention of a curious traveller.

The cataracts in Cumberland are rivalled by a remarkable fall of the Tees, on the west of the county of Durham, over which is a bridge suspended by chains, seldom passed but by the adventurous miners; nor must Asgarth force, in Yorkshire, be passed in silence.

In Perthshire is one of the most considerable cataracts in all Scotland: it is on the river Keith, which is famous for its salmon-fishery, and is near the Blair of Dromond; the violent noise produced from this fall of water is such, as to stun those who approach it.

The western coast of Ross-shire, is peculiarly distinguished by natural curiosities of this and similar kinds; especially by the grand cataract of KIRKAG river, and the cave of GANDEMAN, near Assynt point. The cascade of GLAMMA, in the heights of Glen Elchaig, is truly sublime, amidst the constant darkness of hills and woods. Ben Nevis will, of course, attract notice from its singular form and elevation. According to Mr. Williams, it consists of one solid mass of red granite, which he traced at the base for four miles along the course of a rivulet on the east; the height of this mass he computes at 3600 feet, and above it are stratified rocks, the nature of which he does not explain; but, he says, that those on the summit are so hard and tough, that wrought iron falls short of them. The stupendous precipice, on the north-east side, exhibitsal most an entire section of the mountain. In Argyleshire, the marine cataract of Loch Etif, the beautiful lake of Awe, and environs of Inverary, present the chief objects of curiosity.

The SHANNON, which is the largest river in Ireland, offers a prodigious cataract. It rises in the county of Leitrim, in the province of Connaught, which it divides from Leinster and Munster, and running from north to south, after forming several lakes, turns to the west, and falls into the Atlantic Ocean, after a course of one

For the Gallery of Nature & Art.

HIGH FORCE, OR FALL OF THE TEES ON THE WEST OF DURHAM.

hundred and forty-five miles. This river is in most parts wide and deep, and has within it several fine and fruitful islands, with a fertile soil on both its banks: but it is not navigable above fifty miles for ships, on account of its cataract.

At Powerscourt we also meet with a noble cataract, where the water is said, but probably with much exaggeration, to fall three hundred feet perpendicular, which is a greater descent than that of any other cataract in any part of the world.

NORTH AMERICA in its lakes and cataracts surpasses all other parts of the world. That of Niagara we have already mentioned.

The FALLS of ST. ANTHONY, on the river Mississippi, in latitude 44° 30′ north, descend from a perpendicular height of thirty feet, and are upward of two hundred and fifty yards wide, whilst the shore on each side is a level flat, without any intervening rock or precipice.

There are no remarkable rivers that extend far i to the state of New Jersey; but that named *Passaick*, or *Pasaic*, which discharges itself into the sea to the northward of it, has a remarkable cataract, about twenty miles from its mouth, where it is about forty yards broad, and runs with a very swift current, till arriving at a deep chasm or cleft, which crosses the channel, it falls about seventy feet perpendicular in one entire sheet. One end of the cliff is closed up, and the water rushes out at the other with incredible rapidity, in an acute angle, to its former direction, and is received into a large bason. Thence it takes a winding course through the rocks, and spreads again into a very considerable channel. The cleft is from four to twelve feet broad. When Mr. Burnaby saw it, the spray formed two beautiful rainbows, a primary and secondary, which greatly assisted in producing as fine a scene as imagination can conceive. This extraordinary phænomenon is supposed to have been produced by an earthquake. What greatly heightens this scene, is another fall, though of less magnificence, about thirty yards above.

SECTION X.

Lakes, Lochs, and Loughs.

I. *Introductory Remarks.*

THESE terms are synonymous, or rather, perhaps, may be regarded by the etymologist as universal; for the *lough* of Ireland is the *loch* of Scotland, and both are the *lake* of England; each term being derived from the Latin *lacus*, or the Greek λακκος, of similar import, and varied in its orthography and pronunciation by a mere provincial distinction.

Lakes or loughs have a very close connexion with bogs, as these last have with moors or mosses: a bog or moss being little more than a lake loaded with vegetable matter, usually of aquatic origin *. This connexion is well pointed out by Mr. W. King in the following article, chiefly devoted to the loughs of Ireland; and which we take from the Philosophical Transactions.

As to the origin of bogs, it is to be observed, that there are few places in our northern world but have been noted for them, as well as Ireland; every barbarous ill-inhabited country has them.—I take the loca palustria, or paludes, to be the very same we call bogs, the ancient Gauls, Germans, and Britons, retiring, when beaten, to the paludes, is just what we have experienced in the Irish, and we shall find those places in Italy that were barbarous, such as Liguria, were infested with them, so that the true cause of them seems to be the want of industry. To show this, we are to consider, that Ireland abounds in springs; that these springs are mostly dry in the summer, and the grass and weeds grow thick about those places. In the winter they swell and run, and soften and loosen all the earth about them. Now that swerd or surface of the earth, which consists of the roots of grass, being lifted up and made fuzzy or spongy by the water in the winter, is dried in the spring, and does not fall together, but wither in a tuft, and new grass spring through it, which the next winter is again lifted up; and thus the spring is still more and more stopped, and the swerd grows thicker and thicker, till at first it makes what is

* For bogs, mosses, and the production of peat, see chap. xxvi. of the present part of our work.

called a quaking bog, and as it rises and becomes drier, and the grass roots and other vegetables become more putrid, together with the mud and slime of the water, it acquires a blackness, and becomes what is called a turf bog. I believe when the vegetables rot, the saline particles are generally carried away with the water, in which they are dissolved; but the oily or sulphureous remain and float on the water; and this is that which gives turf its inflammability. To make this appear, it is to be observed, that in Ireland the highest mountains are covered with bogs as well as the plains, because the mountains abound much in springs. Now these being uninhabited, and no care being taken to clear the springs, whole mountains are thus over-run with bogs.

It is to be observed also, that Ireland abounds in moss more than probably any other country, insomuch that it is very apt to spoil fruit-trees and quicksets. This moss is of divers kinds, and that which grows in bogs is remarkable; for the light spongy turf is nothing but a congeries of the threads of this moss, before it be sufficiently rotten; and then the turf looks white, and is light. It is seen in such quantities and is so tough, that the turf-spades cannot cut it.—In the north of Ireland they call it old-wives tow, as it is not much unlike flax; the turf-holes in time grow up with it again, as well as all the little gutters in the bogs; and to it the red or turf-bog is probably owing; and from it even the hardened turf, when broken, is stringy, though there plainly appear in it parts of other vegetables; and it is probable that the seed of this bog moss, when it falls on dry and parched ground, produces heath.

It is further to be observed, that the bottom of bogs is generally a kind of white clay, or rather sandy marl; that a little water makes it exceedingly soft; and when dry, it is all dust; so that the roots of the grass do not stick fast in it; but a little wet loosens them, and the water easily gets in between the surface of the earth and them, and lifts up the surface, as a dropsy doth the skin. Again, bogs are generally higher than the land about them, and highest in the middle; the chief springs that cause them being commonly about the middle, from whence they dilate themselves by degrees; and besides if a deep trench be cut through a bog, you will find the original spring, and vast quantities of water will be discharged, and the bog subside.

It must be allowed that there are quaking bogs otherwise pro-

duced. When a stream or spring runs through a flat, it fills with weeds in summer, and trees fall across and dam it up; then in winter the water stagnates more and more every year, till the whole flat is covered; then there grows up a coarse kind of grass peculiar to these bogs; this grass grows in tufts, and their roots consolidate together, and yearly grow higher, even to the height of a man; the grass rots in winter, and fall on the tufts, and the seed with it, which springs up next year, and so still makes an addition; sometimes the tops of flags and grass are interwoven on the surface of the water, and this gradually becomes thicker, till it lie like a cover on the water; then herbs take root in it, and by a plexus of the roots it becomes very strong, so as to bear a man. Some of these bogs will rise before and behind, and sink where a man stands to a considerable depth; underneath is clear water: even these in time will become red bogs; but may easily be turned into meadow by clearing a trench to let the water run off.

The inconveniences of these bogs are very great; a considerable part of the kingdom being rendered useless by them; they keep people at a distance from each other, and consequently interrupt them in their affairs. Generally, the land which should be our meadows, and the finest plains are covered with bogs; this is observed over all Connaught, but more especially in Longford and also in Westmeath, and in the north of Ireland. These bogs greatly obstruct the passing from place to place; and on this account the roads are very crooked, or they are made at vast expense through bogs. The bogs are a great destruction to cattle, the chief commodity of Ireland; for in the spring, when they are weak and hungry, the edges of the bogs have commonly grass, and the cattle venturing in to get it, fall into pits or sloughs, and are either drowned or hurt in the pulling out; the number of cattle lost this way is incredible. The bogs are a shelter and refuge to outlaws and thieves.

The fogs and vapours that arise from them are commonly putrid and stinking, and unwholesome: for the rain that falls on them will not sink, there being hardly any substance of its softness more impenetrable to rain than turf, and therefore rain-water stands on them, and in their pits, where it corrupts, and is exhaled all by the sun, very little of it running away, which must of necessity infect the air. The bogs also corrupt the water, both as to its colour and taste; for the colour of the water that stands in the pits, or lies on

the surface of the bogs, is tinctured by the reddish black colour of the turf; and when a shower comes that makes these pits overflow, the water that runs over tinctures all it meets, and gives both its colour and stink to many of the rivers.

The natives however had formerly some advantage from the woods and bogs; as by them they were preserved from the conquest of the English; and probably a little remembrance of this makes them still build near them: it was then an advantage to them to have their country impassable, and the fewer strangers came near them, they lived the easier; for they had no inns, every house where you came was your inn; and you said no more, but put off your brogues and sat down by the fire; and still the natural Irish hate to mend high-ways, and will often shut them up, and change them, being unwilling strangers should come and burthen them. Though they are very inconvenient, yet they are of some use; for most persons have their fuel from them, Turf is accounted a tolerably sweet fire; and having very impoliticly destroyed our wood, and not as yet found stone coal, except in few places, we could hardly live without some bogs; when the turf is charred, it serves to work iron, and even to make it a bloomery or iron-work: turf charred I reckon the sweetest and wholesomest fire that can be; fitter for a chamber, and for consumptive people, than either wood, stone coal, or charcoal.

Turf-bogs preserve things a long time: a corpse will lie entire in one for several years; also trees are found sound and entire in them, and even birch and alder that are very subject to rot; such trees burn very well, and serve for torches in the night.

All the inconveniences of the bogs may be remedied, and may be made useful by draining them; and all or most of them have a sufficient fall for that purpose. The great objection against them is the expence, and it is commonly thought that it would cost much more than would purchase an equal piece of good ground; for an acre of good land in most parts of Ireland is about four shillings per annum, and the purchase fourteen or fifteen years, so that three pounds will purchase an acre of good land; and it is very doubtful whether that sum will reduce a bog; but this is far from the fact, as most bogs would well reward the expense of draining them.

As to loughs or lakes, the natural improvement of them, is first to drain them as low as possible; and then turn the residue of the wa-

ter into fish-ponds; by planting a few trees about them, they may be made both useful and ornamental. As to those places called turloughs, *quasi terreni lacus*, or land-lakes; they answer the name very well, being lakes one part of the year of considerable depth, and level smooth fields the rest. There are holes in these, out of which the water rises in winter, and retires again in summer; many hundred acres being drowned by them, and those the most pleasant and profitable land in the country: the soil is commonly a marle, which, by its stiffness, hinders the water from turning it into a bog; and immediately when the water is gone, it hardens, and becomes an even grassy field; these, if they could be drained, would be fit for any use; they would make meadow; or bear any grain, but especially rape, which is very profitable. The lakes are chiefly in Connaught; and their cause is obvious enough, it being a stony hilly country; these hills have cavities in them, through which the water passes: it is common to have a rivulet sink on one side of a hill, and rise a mile or half a mile from the place: the brooks are generally dry in summer; the water sinking between the rocks, and running under ground; insomuch as that in some places where they are overflowed in winter, they are forced in summer to send their cattle many miles for water. There is one place on a hill near Tuam, between two of these turloughs, where there is a hill called the Devil's Mill, at which a great noise is heard, like that of water under a bridge: when there is a flood in winter, one of the turloughs overflows, and vents itself into the hole, and the noise probably proceeds from a subterraneous stream; which in summer has room enough to vent all its water; but in winter, when rain falls, the passages between the rocks cannot discharge it, and therefore it regurgitates and covers the flats.

These turloughs are hard to drain; being often encompassed with hills, and then it is not to be accomplished: often they have a vent, by which they send out a considerable stream; and then it is only making that passage as low as the bottom of the flat, and that will prevent the overflowing; it sometimes happens that the flats are as low as the neighbouring rivulets, and probably they are filled by them; and then it is not only necessary to make the passage from the flat to the rivulet, but also to sink the rivulet, which is very troublesome, the passage to be cut being commonly rocky.

[*Phil. Trans. Abr.* 1685.]

2. *General Survey of Lakes chiefly worthy of Notice in different Quarters of the World.*

THIS interesting branch of natural science extends so widely, and is so captivating from the beauty and variety of the features it unfolds to us, that it is difficult to comprise the present division within due bounds. We shall limit it, however, to those lakes which possess somewhat of a general character, or at least whose character is not so prominent as to be entitled to any peculiarity of delineation; and shall reserve a few of those of this last description for another division.

ASIA.

In describing the most remarkable lakes which are found in various parts of the world, we shall begin with that large body of water which is improperly called the CASPIAN SEA, as it has no visible connection with the ocean, nor does it ebb and flow; but it is undoubtedly the greatest lake in the eastern hemisphere of the globe. It is bounded on the north by the country of the Calmuc Tartars, on the east by Bacharia and part of Persia, on the south by another part of Persia, and on the west by Persia and Circassia. It is situated between 36° 40′ and 47° north latitude, and between 47° 50′ and 50° east longitude, and is about four hundred miles in length from north to south, and three hundred in breadth from east to west; but in many places it is much narrower. The water is salt; and, at some distance from the shore, Mr. Hanway endeavoured in vain to find a bottom with a line of four hundred and fifty fathoms. The water has risen, within the last half century, so considerably, that it has made great inroads on the Russian side for several miles, both to the east and west of the Volga, and has rendered the adjacent country extremely marshy.

The lake BAIKAL, in Siberia, on the road between Moscow and China, is of great extent from north to south, but narrow in breadth, reaching from 51° to 55° north latitude. It abounds with sturgeon, and that amphibious animal the seal.

AFRICA.

THE lake of DAMBEA, in Upper Ethiopia, is the only one worthy of notice in this arid and sandy quarter of the world, and is called by the natives the sea of *Tzana,* from the largest island in it. This lake

has been considered as the source of the Nile, which flows out of it, as already mentioned. It contains about twenty-one islands, Bruce says eleven, some of which are very fertile, and are covered with groves of orange and citron trees, and in seven or eight of them are old monasteries, which appear to have been elegant structures. Its greatest extent, which is in the direction of north-east and south-west, has been computed to be about ninety miles long and thirty-six broad; but Mr. Bruce has reduced its greatest length to thirty-five miles, although on his general map its extent is not three minutes short of a degree of latitude.

EUROPE.

THE principal lakes in the western part of the Russian empire are the following:

The LAKE of LADOGA, situated between the gulf of Finland and the lake of Onega, one hundred and fifty miles in length, and ninety in breadth. It is esteemed the largest lake in Europe; and is supposed to exceed any other for its plenty of fishes, among which are also seals. This lake is full of quicksands, which being moved from place to place by the frequent storms to which it is subject, form several shelves along its course, which often prove fatal to the flat-bottomed vessels of the Russians. This induced Peter the Great to cause a canal, near seventy English miles in length, seventy feet in breadth, and ten or eleven deep, to be cut, at a vast expense, from the south-west extremity of this lake to the sea. This great work was begun in the year 1718, and, though vigorously prosecuted, was not completed till the year 1732, in the reign of the Empress Anne. The canal has twenty-five sluices or locks, and several rivers run into it. At the distance of every werst along its banks, is a pillar marked with the number of wersts; and it is the constant employment of a regiment of soldiers to keep the canal in repair; for this purpose they are quartered in different places on its banks. In summer time it is covered with floats and vessels, which pay toll in proportion to the value of their cargo.

The lake of ONEGA is situated between the lake of Ladoga and the White Sea, and has a communication with the former by means of the river Swir. It is one hundred and eighty wersts in length, and about eighty in breadth; and though its waters are fresh, seals are often seen in it.

The lake of PEIPUS, in Livonia, is nearly seventy miles in length,

Engraved by Scott from a Drawing by Craig. For the Gallery of Nature & Art.

VIEW ON THE LAKE LADOGA.

London, Published by R. Wilks, 89 Chancery Lane, Jan. 1 1814

and about forty miles in breadth. It abounds with fishes, and runs into the gulf of Finland by the river Narva.

In Sweden Proper, which has many rivers, there are a still greater number of lakes. The principal of the latter is the lake of MALER, which is situated between Upland, Sudermanland, and Westmanland. It is seventy-two miles in length, yields great plenty of fishes, and is said to contain twelve hundred and ninety islands. It has a communication with the sea through the mouths of the north and south rivers, which enter it near Stockholm, and its banks are beautifully diversified with towns, castles, churches, noblemen's seats, and other edifices.

There are twenty-three lakes in East Gothland, the most remarkable of which is the WETTER, which extends ninety miles in length, and fifteen in breadth, and contains two or three islands. It has but one outlet, which is by the river Motala, though above forty little streams discharge themselves into it. This lake is said to lie above a hundred feet higher than either the Baltic or the North Sea, and is deep and clear, but very boisterous in winter. Along the banks of the lake Wetter, are found agate, cornelians, touch stone, and rattle-stone.

The celebrated lake of ZIRKNIZER in the Germanic province of Carniola, we have already described *; it takes its name from the neighbouring market-town, and is encompassed with wild, rough, and stony mountains; but round it also lie two citadels, nine villages, and twenty churches.

The lake of CONSTANCE is one of the great boundaries which separate Swisserland from Germany; the broadest part extends into Swisserland, while that towards Germany divides itself into two arms, one of which is called the *Zellersee*, or lake of Zell, and the other the *Bodmen, Ueberlingersee*, or lake of Ueberlingen. In the latter is the island of *Meinau*, which is about a mile in circumference, and not many years ago belonged to the knights of the Teutonic order; in the former is the island of *Reichenau*. The whole lake, from Bregentz to Zell, is also distinguished by two appellations; the part from Bregentz to Constance being called the *Upper Lake*, and that from Constance to Zell the *Lower Lake*: Mr. Coxe calls it "the Inferior Lake of Constance, or the Zeller See;" the extent of which from Stein to Constance, he says, is sixteen

* See Section iv, 6, of the present chapter.

miles, and from the latter to Zell, its greatest breadth, about ten. The latter is between twenty and thirty fathoms deep, and has along its banks many cities, towns, and villages; yet the Upper Lake surpasses it, for it is no where less than fifty fathoms deep, and its greatest depth is said to be three hundred and fifty; but it is considerably deeper in summer than in winter, occasioned by the melting of the snow upon the neighbouring mountains. Here is also its greatest breadth; for between Buchorn on the one side, and Roschach on the other, is no less than five leagues. Near Lindau and Bregentz, beside the fishes commonly caught in those parts, is a kind of salmon-trout, which being pickled, when full grown, are exported as a rarity. They generally weigh between thirty and forty pounds. As the fishermen cannot always make a good market of such large fishes, they tie a bit of wood on a line, which having passed through the fishes gills, they throw them again into the water, and tie the other end of the line to a stake near their huts; thus, without any danger of losing their game, allowing them a range of thirty or forty paces to swim in, and preserving them alive and sound till they meet with a market. These fishes are caught only three months in the year.

In the middle of the Lower Lake, the island of REICHENAU lies; and on account of its fertility, and the wealth of the abbey built there, is not improperly styled *Reichenau*, or *Augia-dives*. The island is about three miles long and one broad, abounding with fine vineyards, and all kinds of fruit.

The lake of GENEVA resembles the sea, both in the colour of its water, the storms that are raised on it, and in the ravages it makes on its banks: it is as little subject to frost as the lake of Constance. It receives different names from the coasts it washes, and has in summer something like the ebbing and flowing of the tide, occasioned by the melting of the snows, that fall more copiously into it at noon, than at other times of the day. It has, or rather had, formerly, five different states bordering on it; France, the duchy of Savoy, the canton of Berne, the bishopric of Sitten, and the republic of Geneva. This lake is in shape like a half-moon, whose convex side looks towards Swisserland; so that it is sixteen leagues in length on this side, while towards Savoy it does not exceed twelve. It is pretty narrow at both ends; but widens by degrees to the middle, where it is twenty-five miles over. As to its depth, it is said in some places to be unfathomable, and is therefore navigable

by larger vessels than are commonly seen in rivers. Near Villeneuve, the Rhone discharges itself into it with such rapidity, that for the distance of half a league, the river water, which is very foul, continues unmixed with that lake, which is very clear; "but afterward," says Keysler, "there is no visible distinction, though various ancient, and several modern writers, affirm the contrary." Formerly this lake afforded trouts of fifty or sixty pounds weight; but now one of twenty or thirty is reckoned very large.

The Rhone, at its efflux, forms an island, on which, together with the banks on both sides, stands the city of Geneva, which is thus divided into three unequal parts, that have a communication by four bridges, and is situated in 46° 12′ north latitude, and in 6° east longitude from Greenwich. The greatest part of the city is seated on a hill, and has its view bounded on all sides by several ranges of mountains; but these are at so great a distance, that they leave open a surprising variety of beautiful prospects, and, from their situation, cover the country they inclose from all winds except the south and north, to the last of which the inhabitants of this city ascribe the healthfulness of the air; for as the Alps surround the city on all sides, forming a vast bason, within which is a well-watered country, there would be a constant stagnation of vapours, did not the north wind put them in motion, and scatter them from time to time. From this situation, as Mr. Addison observes, the sun rises later at Geneva, and sets sooner, than in other places of the same latitude; and the tops of the neighbouring mountains are covered with light above half an hour after the sun is down at Geneva. These mountains also much increase the heats of summer, and form an horizon that has something very singular and agreeable. On the one hand, a long range of hills, distinguished by the name of Mount Jura, is covered with pasture and vineyards; and on the other, huge precipices, formed of naked rocks, rise in a thousand odd figures, and being cleft in some places, discover high mountains of snow at the distance of several leagues behind them. To the southward, the hills rising more insensibly, open to the eye a vast uninterrupted prospect; but the most beautiful view is that of the lake, and its borders, which lie north of the town. There are few of the Swiss poets who have not acknowledged the inspiration of this enchanting scenery.

Geneva is by far the most populous town in Switzerland, its in-

habitants amounting, according to Mr. Coxe, to twenty-four thousand souls; whilst Zurich, which comes next to it in respect of population, contains scarcely thirteen thousand.

The lake of ZURICH is one of the largest in Switzerland (those of Constance and Geneva excepted), it being, according to Mr. Coxe, near ten leagues in length, and about one in breadth. The prospect from it is extremely delightful, the little eminences by which it is bordered being all over diversified with corn-fields, vineyards, villages, and towns: farther back is a gradual ascent of larger hills, terminating in the stupendous mountains of Glaris, Schwitz, and the Grisons, whose summits are always covered with snow; the whole forming a scene truly picturesque, lively, and diversified. The Rhine waters the north side of the canton of Zurich, where it is joined by the Thur, the Toss, and other smaller streams. Out of the lake of Zurich issues a river, which flows through the town, and having a little below it received the Hill, begins to be called the Limmat; till traversing the country of Baden, it at last loses itself in the Aar.

The lake of YVERDUN, or NEUCHATEL, stretches, from south to north, about twenty miles in length, and in some places about five miles in breadth. According to M. de Luc, this lake is a hundred and fifty-nine French feet above that of Geneva.

The lake of BOURGET, in Savoy, is remarkable for breeding a fish which is unknown in other countries, called *lavaretta* *, which frequently weighs four or five pounds, is sold for a good price, and is extremely well flavoured.

The lake of URANA, in Dalmatia, which is seated on the north-eastern coast of the Adriatic Sea, and is described by the Abbé Fortis as of twelve miles extent, deserves to be mentioned on account of a project which was formed by a private person, and partly put in execution, to cut a passage by which the water might be discharged into the Adriatic: the course was to be cut through an isthmus of solid marble for half a mile; the attempt, however, was soon abandoned. The object in view by making this outlet, was to drain, and, if possible, to render fit for cultivation, about ten thousand acres of land, which lay overspread with water. The Abbé inspected

* This s the common opinion: but it is not quite correct. The lavaret is met with also in many other parts of Europe towards the north. It is a species of guinia, the salmo lavaretus of Linnéus.—EDITOR.

this effort, accompanied by the Bishop of Derry, afterwards Earl of Bristol, and it appeared to them at the time to be altogether illusory.

Cherso is a fruitful island, at one time belonging to the Venetians, and which was once much more considerable than at present; here stood an ancient temple to Diana, which formerly gave name to the island, and is noticed by Apollonius of Rhodes. It is situated in a gulf, formed by the south-eastern coast of Istria with the shores of Croatia and Dalmatia, latitude 45° 10′ north. On this island is no river, but a lake which possesses very singular properties; it is called *Jessero*, analogous to Jezoro, a word still used by the Poles to express a lake or standing pool. The water is not always constant in its confines; sometimes it leaves a part dry for three or four years, and then rises again; at other times it rises above its usual level, and after a certain time forsakes the usurped ground *. The proprietors of the contiguous lands sow them, when free of the water, and know how to take their measures by observing the ordinary periods. The first year they sow maize, or Indian corn, which yields no great crop, on account of the weeds that spring up with the grain, and which are not then to be extirpated, but the two or three subsequent years they have very plentiful crops by sowing wheat. The fifth year they forbear to sow, expecting the rising of the waters, which seldom fails to happen. In this lake are pikes of above thirty pounds weight, with tenches, eels, and other fresh-water fish of exquisite taste.

VENICE, the capital and formerly seat of government of the republic of that name, is situated in 45° 26′ north latitude, and in 12° 4′ east longitude from Greenwich, and from its Laguna is entitled to a notice in the present place. It makes a very noble appearance at a distance, seeming, from its being built on a multitude of very small islands, to float on the sea, or rather, with its stately buildings and steeples, to rise out of it. The number of these islands still remains uncertain, some reckoning sixty, others seventy-two, and others again asserting that they amount to one hundred and thirty-eight; but the latter must comprehend in their calculation all those places that have been

* See for a similar phænomenon the description of lake Quirknizen, Sect. iv. 6. of the present chapter.

gradually raised in the Laguna, by driving piles in the ground, and building on them.

The LAGUNA, or marshy lake, which lies between the city and the continent, is five Italian miles in breadth, and too shallow for large ships: by the attention of the republic it is prevented from becoming a part of the continent, and from being ever frozen so as to bear an army; hence the city is inaccessible on this side. Toward the sea the access is also difficult; but the safe and navigable parts are pointed out by piles, which, at the approach of an enemy's fleet, may be easily cut away. Beside, as a considerable number of men of war and gallies may be expeditiously fitted out for sea from the dock, which contains vast quantities of naval stores, the city is secure from any attack either by land or water, and is sufficiently strong without fortifications. The fishes, which are caught at the very doors of the houses, may be esteemed a good preservative against a famine, and the several canals leading to the city, between the sand-banks and marshy shallows, are, at a vast expense, kept clear of the mud and slime brought with the flood. The return of the sea is something later here than every sixth hour, and it generally rises between four and five feet, keeping the water between the islands of the city in continual motion: but some of these canals being very narrow, the mud is not so effectually carried off as to prevent ill smells in hot weather.

LAGO MAGGIORE, in the duchy of Milan, is a most extraordinary lake, sixty-five Italian miles in length, in most places six broad, and its depth about the middle eight fathoms. Toward Switzerland it terminates in a canal that is of vast advantage to commerce. The lake is every way environed with hills covered with vineyards and summer-houses, which above the vineyards are plantations of chesnut-trees, the fruit of which is consumed in such quantities, that when chesnuts are in great plenty, the price of corn falls, especially at Genoa. Along the banks of the lake are fine rows of trees, and walks arched with vine branches, especially near the town of Alesco. This beautiful prospect is farther heightened by large natural cascades falling from the mountains.

Two leagues from Sesti the lake begins to widen, and on entering the bay appear the two celebrated *Isola Bella* and *Isola Madre*; the former lately belonging to Count Borromeo, and the

latter to the Emperor. These two islands have been compared to two pyramids of sweetmeats, adorned with green festoons and flowers. At one end of the garden of the Isola Bella are ten terraces, the perpendicular height of which, taken together, says Keysler, is sixty ells above the height of the water, each ell consisting of three spans. These terraces decrease proportionably in their circuit as they rise toward the top of the hill, where an oblong area, paved with fine stone, and surrounded with a ballustrade, affords a most delightful prospect. It is in length from forty-five to fifty common paces, and on every side stands a range of marble statues of a gigantic size. The rain-water runs into cisterns underneath, to which also other water is conveyed in order to supply the water-works. Round every terrace is a pleasant walk, and at the four angles are large statues and pyramids placed alternately. The walls from the bottom to the top are covered with laurel hedges, and espaliers of orange, lemon, peach-trees, &c. The laurels stand in the open air during the whole winter; but the lemon and orange-trees are sheltered over with a covering of boards, and in sharp weather cherished with heat, from fires provided for that purpose, at a great expense. The annual charges of this Borromean paradise amount to forty thousand Piedmontese livres. But to raise so noble a superstructure upon such a foundation, and to bring these islands to their present incomparable beauty and magnificence, seems an undertaking beyond even the revenue of a prince to accomplish. The Isola Bella was, somewhat more than a century ago, only a barren rock, to which every basket of earth, and whatever is found there, must have been brought by boats at a prodigious expense.

The garden of Isola Bella has a south aspect, and at the two angles of its front are two round towers, in which are very lofty apartments, adorned with red and black marble. Here is also a covered gallery, supported by stone columns, and shaded with lemon trees. On the other side, that is, toward the east, is a delightful walk of large orange-trees, disposed in four or five rows. At a small distance is a fine grove of olives, with narrow walks, and a cascade that falls down above twenty steps. Here is also a plantation of large pomegranate-trees. The lake comes up so close both to the palace and gardens, as scarcely to leave so much dry ground as to set one's foot upon, except a small space before the north front of the palace, which was a fine prospect towards

Isola. On the east and west sides are large vaults, upon which the earth has been raised to the height above-mentioned; and the whole may be compared to the hanging gardens of antiquity. These vaults are not only a foundation for the soil, but an ornament to the gardens, all of them resembling so many grottos. Near the palace are kept in a shed, built for that purpose, three fine gondolas for parties of pleasure upon the water.

From Isola Bella to Isola Madre is about half an hour's sailing, though their great height makes them appear much nearer. The latter has seven terraces, which are high, but sloping, and at a considerable distance from each other, by which means it appears to be lower than Isola Bella, though according to the original pnla they are of an equal height. The greatest part of the external foundation of Isola Madre is a high perpendicular rock, projecting considerably over the water, so that it did not require so much masonry as Isola Bella. That part of the front of the palace only is completed which looks toward Sesti and the above island, and is adorned with fine paintings of flowers, portraits, and landscapes.

The garden of this island also abounds with vegetable beauties, particularly a fine espalier of citron-trees, with a low contre-espalier of orange-trees, an arched walk of cedars, a smaller espalier of jessamine, an espalier of acacia, and another of rosemary not less than eight feet in height. Here are also several small groves of laurel, with walks cut through them. Some of these trees are of uncommon thickness; and one of these espaliers of laurels is above eighteen feet high: such a hedge, by means of the mildness of the air, and its being fenced from the north wind by the neighbouring mountains, shoots up to this height in six or seven years.

The Isola Madre is a secure place for keeping pheasants, which are easily confined here on account of the great breadth of the lake: for when any of them attempt to fly over it, they soon flag, and drop into the water, from which they are immediately taken up by a waterman who puts off for that purpose, and brings them back. This, however, seldom happens; for as the island is larger than Isola Bella, and abounds with every thing proper for them, as well as places for shelter, the birds seldom attempt to make their escape. There is a little house built for the young pheasants, and near it a beautiful grove of lofty cypress-trees. This appears to be the finest part of the island, and recals to one's mind the fabu-

lous descriptions that have been given of enchanted groves and islands. The walks through this cedar plantation lead, by a descent, to a summer-house near the lake. The shores of both islands are set round with painted flower-pots; and when any foreign prince comes in the night, or makes any stay here, both islands are illuminated with lights of all colours, which exhibit a very glorious spectacle.

The territory of PERUGIA contains a pretty large lake, anciently called *Thrasimene*, but at present the lake of *Perugia*, in which are three islands. Between this lake and a high mountain near Cortona, in the dominions of Florence, is a long valley with only one narrow entrance, where Hannibal defeated Flaminius the Roman general.

THE CAPE OF BOLSENA, a small town most delightfully situated in the patrimony of St. Peter, is thirty-five Italian miles in circuit. The mountains which environ it are covered with oaks, and form expansive and august amphitheatres. Here is said to have been wrought by the host (the elements of the eucharist) when carried in procession, the miracle which gave occasion to the institution of the festival of Corpus Christi. Near this place are seen, on an eminence, the walls of the Etrurian city Volsinium, in ruins.

Four Italian miles from Tivoli, a town of great antiquity in the Campagna, and seventeen miles north-east of Rome, lies the lake of SOLFATARA, formerly called *Lacus Albutus*, in which are sixteen floating islands. Dr. Moore asserts that these islands are nothing else than bundles of bulrushes springing from a thin soil, formed by dust and sand blown from the adjacent ground, and glewed together by the bitumen which swims on the surface of this lake, and the sulphur with which its waters are impregnated. Some of these islands are twelve or fifteen yards in length; the soil is sufficiently strong to bear five or six people, who, by means of a pole, may move to different parts of the lake, as if they were in a boat. This lake empties itself by a whitish muddy stream into the Teverone, the ancient Anio; a vapour of a sulphureous smell arising from it as it flows. The ground near this rivulet, as also around the waters of the lake, resounds as if it were hollow when a horse gallops over it. The water of the lake has the singular quality of covering every substance which it touches with a hard, calcareous

or petrifying matter*. On throwing a bundle of shrubs or small sticks into it, they will in a few days be covered with a white crust; but what seems still more extraordinary, this incrustating quality is not so strong in the lake itself as in the canal, or little rivulet that runs from it, and the farther the water has flowed from the lake, till it is quite lost in the Anio, the stronger this quality becomes. These small round incrustations which cover the sand and pebbles, resembling sugar plumbs, are called Confecti di Tivoli, or confections of Tivoli. Fishes are found in the Anio, both above and below Tivoli, till it receives the Solfatara, after which, during the rest of its course to the Tiber there are none. The waters of this lake had a high medicinal reputation anciently, but they are in no esteem at present.

The lake of AGNANO, in the kingdom of Naples, is not far distant from the Grotto of Pausilipo, which as an artificial excavation will be described in Part III. of this Work. The communication between these two remarkable places is by a very pleasant road, between fine vineyards. This lake is a perfect circle, about an Italian mile in circumference. At high water, in some parts of it, is seen a strong ebullition. On approaching it, one is sensible of the motion of the water, which possibly proceeds from the ascent of the effluvia. The tenches and eels in this lake have in winter a very good flavour, but in summer are not eatable, which is in some measure imputed to the great quantities of flax and hemp brought thither from all the neighbouring parts, which are soaked in this water for the purpose of mellowing them.

Near this lake stand the *sudatories* of *St. Germano*, which consist of several apartments built with stone, where the heat and sulphureous vapours issuing from the earth soon cause a profuse sweat; in some places the wall is too hot for the hand to bear it, and yet the heat is supportable in the hottest room, especially if you stoop toward the ground. The same observation is made on the baths of *Tritoli*. The patients are put into rooms of different degrees of heat, according to the nature of their complaint; and in the sudatories of St. Germano, which are said to be very efficacious in the gout, debilities, inward heats, &c. they never stay above a quarter of an hour at a time.

* See a similar property in the water of Loch-neagh in the subdivision 3, of this section.

Within an hundred paces of these salubrious sudatories is a small natural cavern, known by the name of "*Grotto del Cané*, or *Dog's Grotto*," which we have already described *. As we have also the general face of the valley of Solfatara itself †.

This lake is in some places an hundred and eighty feet deep; and some old walls standing near it, are supposed to be the remains of a temple to Apollo.

Of the lakes in FRANCE, none need be mentioned here but that of THAU, on which is seated the small town of *Frontignac*, or *Frontignan*, seventeen miles to the south-west of Montpelier, celebrated for its excellent muscadine wine, its jar-raisins, and its handsome town-house. This wine is called by the English Frontiniac. The above lake, which is also named *Maguleone*, is twelve leagues in length, and separated from the sea only by a narrow tract of land; but in one place has a communication with the gulf of Lyons, which, according to Busching, takes not its name from the city of Lyons, which is seated at a great distance from the sea, but rather from the violent storms so frequent in this shallow part of the Mediterranean, and which destroy the ships as a furious lion does its prey.

BRITISH ISLES.

In ENGLAND, the adjoining counties of Cumberland, and Westmorland, are so highly celebrated for their lakes, and the beautiful romantic scenery that surrounds them: that we shall more minutely advert to them in the ensuing subdivision of this section. The principal lakes in Cumberland are, *Derwent-water*, *Uls-water*, and *Broad-water*; beside which, *Bassenthwaite*, *Low-water*, *Wasdale*, and *Dalgarth*, are all worthy of notice.

The lake of DERWENT-WATER is in the vale of Keswick: it is three miles in length, and a mile and half wide. Five islands rise out of this lake, which being covered either with turf or trees, add greatly to the beauty of the appearance. On one of these islands is an elegant modern-built house. More to the north-west, the river *Derwent*, after running a short space in a narrow channel,

* See ch. xxv. sect. vii. vol. II.

† See vol. I. ch. xvii. p. 509.

enlarges into the long and narrow lake, called Bassenthwaite, at the termination of which is a remarkable water-fall, named *Lowdore.* The Derwentwater estate was not long since restored to its noble family, subject to a large fee farm rent, for the use of Greenwich hospital.

ULS-WATER is a long and narrow lake, with its southern part in Westmorland, while all the rest is equally divided between the two counties. If a swivel-gun, or even a fowling-piece, be discharged from a boat on this lake, in certain parts of it, the report will reverberate from rock to rock, promontory, cavern, and hill, with an astonishing variation of sound, now dying away upon the ear, and again returning like peals of thunder. This re-echo may be distinctly heard seven times in succession.

Among mountains where eagles build their nests, in the western part of Westmorland, and on the borders of Lancashire, is WINANDER-MERE, the longest and most beautiful lake in England, said to be so called by the Saxons, from its winding banks. It is about ten miles in length from north to south, but in no part is broader than a mile. It is paved as it were at bottom with one continued rock. In some parts it is of a vast depth, and is well stored with a fine fish called *char* *, which is rarely found elsewhere, except among the Alps, and in some of the lakes of America. The Uls-water, already mentioned, has likewise some *char*; but not in such plenty as here. In the forest of Martindale, to the south of Uls-water, the breed of *red deer* still exists, in a wild state.

In WALES, the BELA lake, of Merionethshire, deserves to be spoken of. This country is watered by several rivers, the most of which are connected with lakes, and the principal of which are the *Dee*, the *Avon*, and the *Drurydh*. The Dee has two spring-heads in the eastern part of the county, after the union of which it is supposed to run through the lake *Bala*, or *Pimble-meer*, without mixing its waters with those of the lake; at least the different tribes of fishes seem not to mingle; for it is said, that though the Dee abounds with salmon, none are ever taken in the lake out of the stream of the river; nor does the Dee carry off any guiniads, a fish

* Salmo Carpio and S. Alpinus of Linneus.—Editor.

peculiar to the lake, which resembles the whiting, but tastes like a trout.

The most remarkable lochs, or lakes, in SCOTLAND, are *Lochtay*, *Lochness*, and *Lochleven*, which send forth rivers of the same name with themselves; *Lochlomond*, which sends forth the river Lomond; and *Lochiern*, from which flows the river Iern.

On Lochleven lately resided a collateral relation and namesake of the celebrated Dr. Smollet, to whose memory he raised an obelisk, on the bank near the house in which he was born. Smollet was entitled to this mark of attention; for we are indebted to him for the following beautiful lines to the lake itself.

On Leven's banks, while free to rove,
And tune the rural pipe to love,
I envied not the happiest swain
That ever trod th' Arcadian plain.
Pure stream! in whose transparent wave
My youthful limbs I wont to lave;
No torrents stain thy limpid source;
No rocks impede thy dimpling course,
That sweetly warbles o'er its bed,
With white, round, polish'd pebbles spread;
While, lightly pois'd, the scaly brood,
In myriads, cleave thy crystal flood:
The springing trout, in speckled pride;
The salmon, monarch of the tide;
The ruthless pike, intent on war;
The silver eel, and mottled par.
Devolving from thy parent lake,
A charming maze thy waters make,
By bow'rs of birch, and groves of pine,
And hedges flower'd with eglantine.
Still on thy banks, so gaily green,
May num'rous herds and flocks be seen;
And lasses, chanting o'er the pale;
And shepherds, piping in the dale;
And ancient faith, that knows no guile,
And industry, imbrown'd with toil;

And hearts resolv'd, and hands prepar'd
The blessings they enjoy to guard!

IRELAND abounds more in lakes, or as they were formerly called, *loughs*, than perhaps any other country of the same extent; and especially the provinces of *Ulster* and *Connaught*, in which they are more frequent than in the other provinces of the kingdom. They are usually classed under two denominations; fresh-water lakes, which have no access of the tide, or mixture with the sea, and salt lakes, into which the tide flows, and which may more properly be called inlets of the sea.

Of the fresh-water lakes, one of the most extraordinary is *Lough-lene*, in the county of Kerry, which is remarkable for its singular beauties. It is about six miles in length, and, at a medium, near half as much in breadth; and is interspersed with a variety of beautiful islands, many of them rich in herbage, and well inhabited. Eagles and ospreys are here in great numbers, and the islands and rocks in and around the lake are adorned with groves of the arbutus, which is frequently four feet and an half in circumference, and nine or ten yards high.

Lough-erne and *Lough-neagh* are by much the largest lakes in Ireland. The former is divided into two branches, the upper and lower, which are separated by the water being contracted into the compass of a considerable river for some miles, after which, enlarging itself, it forms the lower lake. This lough, in both its branches, takes its source through the whole length of the county of Fermanagh, from the south-east point to the north-west, nearly dividing it into two equal parts. It abounds with a great variety of fishes, as *pike* of a prodigious size, large *bream*, *roach*, *eels*, and *trout*; but it is chiefly valued for its *salmon*.

Lough-neagh is somewhat of a square form, but indented on every side. It is esteemed the largest lake in Ireland, and is exceeded by few in Europe, being twenty miles long from the north-west point to the south-east, near fifteen miles from the north-east to the south-west, and ten or twelve broad at a medium. Lough neagh communicates its benefits to five counties, Armagh, Tyrone, Londonderry, Antrim, and Down; the latter of which it only touches by a small point on the south-east side. It receives

six considerable rivers, four of lesser note, and several brooks; yet has but one outlet to discharge this great flux of water. It has various peculiarities, and especially that of petrifying vegetables; on which account we shall more minutely notice it in the ensuing subdivision of *Particular Lakes*.

AMERICA.

Nothing distinguishes the northern parts of this division of the world more than its numerous and immense lakes, the five principal of which belong wholly or in part to the province of Canada, or Quebec, and are named *Ontorio*, *Erie*, *Huron*, *Michigan*, and *Superior*. These lie within about seven degrees of latitude, and fourteen of longitude, or from 41° 35′ to 49° north, and from 75° 20′ to 92° west. There are beside many smaller lakes which lie to the eastward and north-westward of these. To the eastward are the lakes *George* and *Champlain*. The most northern visited by the traders is the lake *Bourbon*, which reaches to 51° north latitude; to the south of which is the lake *Winnepeek*, called by the French *Ouinipique*: communicating with the former by a strait. A river extends from lake *Winnepeek* to lake *Superior*, which some geographers have considered as a continuation of the St. Laurence: about midway of this river is the lake *du Bois*, or *Wood* lake; there is likewise lac *Pluie*, or the *Rain* lake, the *Red* lake, and *Niepegon*, with many others still less considerable. Beyond 60° of north latitude, from near Hudson's Bay to 131° west longitude, are other extensive lakes, about which the savage race of *Arathapescow* Indians lead their wandering life. These vast assemblages of fresh waters, which are not put in motion and alternately raised and sunk by tides, are supposed to contribute very considerably to the greater degree of cold which is felt in the northern parts of America than in the same parallels of latitude in Europe.

In describing these lakes, let us begin with the most eastern, and proceed westwardly.

Lake GEORGE, formerly called by the French *lac St. Sacrement*, is about thirty-five miles long from north-east to south-west, but narrow.

Lake CHAMPLAIN is about eighty miles from north to south, and about fourteen miles where broadest. When these two lakes

were first discovered, they were known by no other name than that of "*Iroquois* lakes."

Lake ONTARIO is the least of the five great lakes of Canada; its form is nearly oval; its greatest length being from north-east to south-west. Its circumference is about six hundred miles. Near the south-east part it receives the waters of the Oswego river, and on the north-east discharges itself into the river Cataraqui, which communicates with the St. Laurence, or may be considered as the source of it; though some geographers describe that vast river as uniting the five great lakes, and having its source to the westward of lake Superior. Near to it stood fort *Frontenac*, which was taken from the French in the year 1758, by some provincial troops, under Colonel Bradstreet. At the entrance of Oswego river stood a fort of the same name, which, in the year 1756, was defended by two regiments of provincial troops, when it was attacked and taken by the French, and the garrison cruelly massacred by the savages who followed the French camp.

Lake ERIE extends about three hundred miles from west to north-east. It is widest toward the middle, where it is about seventy miles across from north to south. Carver, a faithful narrator of what he saw, though not to be followed in longitudes and latitudes, says, the navigation of this lake is esteemed more dangerous than any of the other lakes, on account of many high lands which lie on its borders, and which project into the waters, so that whenever sudden storms arise, canoes and boats are frequently lost, as there is no place which affords retreat or shelter. The same writer says there are several islands near the west end so infested with venomous snakes, that it is highly dangerous to land upon them. The water is covered near the banks of these islands with the nymphæa nelumbo or aquatic lilly, the leaves of which spread over the surface, so as to cover it entirely for a great space; on these our traveller saw prodigious numbers of the water-snakes, wreathed up, and basking in the sun.

This lake discharges its waters at the north-east end into the river Niagara, which runs due north and south; is about thirty-six miles in length, and flows into lake Ontario. At the entrance of this river, on its eastern shore, is fort *Niagara*, which was taken from the French in the year 1759, by Sir William Johnston, and was considered as a highly important acquisition. About eighteen

miles farther northward are those stupendous cataracts, which are not to be equalled by any other falls of water on this globe, and which have been already described.

Lake HURON is next in magnitude to lake Superior; its shape is nearly triangular, and it is about a thousand miles in circumference; on the north side of it is an island, nearly an hundred miles in extent from east to west, but in no part above eight miles from north to south; it is called by the Indians *Manataulin*, which signifies a place of spirits. At the west point of the lake are the straits of *Michillimackinac*, which unite with lake *Michegan*; and about fifty miles to the north-east of these straits are those of *St. Marie*, by which lake Huron communicates with lake Superior: they are about forty miles long, and very unequal in breadth: here are falls, but not perpendicular, like those of Niagara, but the waters pass along a sloping bottom, which in that country is called *a rapid:* this continues for nearly three-quarters of a mile. The fall here is not so impetuous as entirely to prevent the navigation of boats and canoes downward. The southern point of lake Huron runs into a strait, which soon after enlarges into a small lake called *St. Claire*, from which runs another strait, which is only distinguished by the French name of *Detroit* (strait); this discharges itself into lake Erie, the distance between which and Huron is eighty miles. Although the water here is level, yet the navigation of large vessels is stopped by a bank of sand. The town of *Detroit*, which contains upward of an hundred houses, is situated on the western banks of this river, or strait, about nine miles below lake St. Claire. At the north-east point a considerable river flows into this lake, called the Souties, from which there is but a short carrying-place to the river of the Attawawas, which discharges itself into the St. Laurence above Montreal.

Lake MICHEGON, to the west of Huron, is long and narrow, extending nearly two hundred miles from north-west to south-east, and forty broad from north to south. Between these two lakes a peninsula is formed, which runs into a point at the north-west, at the straits of Michillimackinac, where is a fort of the same name, which, in the language of the Chippewaw Indians, signifies a tortoise. On the north-west side of this lake is a strait, about forty miles wide, called the grand traverse, in which are many islands, some of which are inhabited by the Ottawaws, and others by the

Pontowattimic Indians. This strait leads into what the French called *Baye Puant* (stinking), but which is now named the *Green Bay;* it is long and narrow, and into it flows a large stream, which rises near the Mississippi, and is denominated the *Fox River;* its banks are inhabited by a powerful tribe of Indians. On the south-west side of the river are the Saukie Indians. Near the borders of this lake are a great number of sand cherries, which are not less remarkable for their manner of growth, than for their exquisite flavour. They are found upon a small shrub, not more than four feet high, the boughs of which are so loaded, that they lie in clusters on the sand. As they grow only on the sand, the warmth of which probably contributes to bring them to such perfection, they are called by the French *cerise de sable**, the size of them does not exceed that of a small musket-ball. Gooseberries and juniper trees, bearing berries of a very fine kind, abound here. Sumack likewise grows here in great plenty, the leaf of which, if gathered when red, is much esteemed by the natives, who mix about an equal quantity of it with their tobacco. Near this lake, and on the borders of all the great lakes, grows a kind of willow, to which the French have given the name of *bois rouge*, or *red wood* †. Its bark, when of one year's growth, is of a fine scarlet colour, but as it grows older it changes into a mixture of grey and red. The stalks of this shrub grow in clusters to the height of six or eight feet, and never exceed an inch in diameter. The Indians scrape the bark, which they dry and powder, and mix with their tobacco, for their winter pipes.

Lake SUPERIOR is entitled to this distinguishing appellation, not only as it surpasses every other American lake in extent, but as being situated on a much more elevated part of the country, the level of its waters being several hundred feet higher than those of the St. Laurence. It may be justly called "the Caspian of America," and is unquestionably the largest expanse of fresh water in the world, being in magnitude equal, or rather surpassing that Asiatic salt water lake, which has been already spoken of. The French are said to have observed of the lakes, that they rise, by imperceptible degrees, to about the height of three feet in seven years and

* Cerasus pygmæa, Linn. Editor.
† Salix rubra, Linn. Edit.

an half, and sink as much in an equal portion of time, so that in fifteen years this watery cycle, if it may be so termed, is completed: a change similar to what has been reported of the Caspian, but performed in one quarter of the time. According to the French charts, the circumference of lake Superior is about fifteen hundred miles. Carver is of opinion, that " if it were coasted round, and the utmost extent of every bay taken, it would exceed sixteen hundred." He coasted near twelve hundred miles on the north and east shores: " When it was calm," says he, " and the sun shone bright, I could sit in my canoe, where the depth was upward of six fathoms, and could plainly see huge piles of stone at the bottom. The water at this time was as pure and transparent as the air, and my canoe seemed as if it hung suspended in that element. It was impossible to look attentively through this limpid medium at the rocks below, for even a few minutes, without feeling the head swim, and the eyes no longer able to view the dazzling scene." This occurred in the month of July, and although the surface of the water, from the heat of the atmosphere, was warm, yet on letting down a cup to the depth of about a fathom, the water drawn thence was so excessively cold, that it had nearly the same effect as ice, when taken into the mouth. This lake is said to receive nearly forty rivers and streams of water; the two principal rivers are the Nipegon, or Alanipegon, and the Michipicooton, the one from the north, and the other from the west. By means of the latter, a communication is formed with the lakes Bourbon or Christianeux, Winnepeek, and du Bois; and in this river some have traced the St. Laurence. A small river on the west, before it enters the lake, has a perpendicular fall from the top of a mountain, of more than six hundred feet, through a very narrow channel. The only passage through which the waters of lake Superior are discharged, is St. Mary's strait, already spoken of. There are many islands in this lake, two of which are very extensive; the largest has been named *Isle Royal*, the other *Phillipaux*, which last is supposed to be nearly an hundred miles from east to west, but in no part more than forty miles from north to south. Miropau Isle is likewise of considerable extent; at the entrance of West bay is a cluster of small islands called " the twelve Apostles. On the south side of the lake is a peninsula, which spreads into the

lake sixty miles, and is called *Chegomegan*. The Indians suppose these islands to be the residence of the Great Spirit.

This lake abounds with fishes, the principal of which are trout and sturgeon. The country to the north and east is very mountainous and barren. Whirtle-berries, of an uncommon size, and fine flavour, grow in great quantities on the mountains, as do black currants and gooseberries; but the most excellent fruit in these parts is a berry resembling a raspberry in its manner of growth, but of a lighter red, much larger, and in flavour more delicious. It grows on a shrub of the nature of a vine, with leaves like the grape.

On the north-west border of lake Superior is what is called "the grand portage;" and there those who go on the north-west trade, many of whom come from Michillimackinac to the lakes De Pluye, Du Bois, &c. carry over their canoes and goods for about nine miles, when they again proceed by water carriage.

There is likewise a great mart for trade about an hundred and fifty miles to the south-west of lake Superior, near the banks of the Mississippi, where that river forms what is called lake *Pepin*. As this was settled to be a place of resort by the French traders, they thought fit to give it a name, and it has ever since been known by that of *La Prairie du Chien*, or *Dog Meadow*. Hither all the Indians who inhabit the adjacent countries resort, and it rather deserves to be named the meadow of concord; for whatever Indians meet in this place, though the nations to which they belong are at war with each other, are obliged to restrain their enmity, and to forbear all hostile acts whilst they continue here. The like conduct is observed at the Red Mountain, which is in the same part of the country, whence they procure the stone of which they make their pipes.

Of the SPANISH Possessions in North America, the province of MEXICO PROPER greatly exceeds the rest, and contains the capital of the same name, which is seated in the lake of Tuscuco, or Mexico. on the east side of a valley, at the foot of a range of hills, in 19° 26′ north latitude, and 101° 12′ west longitude from Greenwich, about a hundred and seventy miles west of the gulf of Mexico, and a hundred and ninety north of Acapulca. Clavigero calls it "the most renowned of all the cities of the new world," and says it is, like Venice, built on several islands.

The lake Tuscuco, he tells us, formerly extended fifteen or seventeen miles from east to west, and something more from north to south, but its present extent is much less, the Spaniards having diverted into new channels many of the rivers which formerly ran into it. The same writer says, that all the water which assembles there is at first sweet, and becomes afterward salt from the nitrous quality of the bed of the lake.

On this lake, and in the city which it encompasses, Cortes and his Spaniards maintained that cruel war against the Mexicans which commenced in the latter end of 1519, and was continued for eight years. Here the gallant Emperor Guatimozin was taken, when endeavouring to escape in a boat, under a disguise, intending, as the last effort, to raise a force in the neighbouring provinces. Into this lake, it has been supposed, a considerable part of the wealth contained in the city, when in the height of its splendor, was precipitated, to prevent its becoming the spoil of their cruel conquerors, when the Mexicans were no longer able to maintain the unequal contest.

Of the southern part of the continent of AMERICA, the principal lake we meet with is MAYACAYBO, in Terra Firma. It communicates with the gulf of Venuzuela, by a strait, on the western coast of which the city of Mayacaybo is situated. This lake is said to be eighty leagues in circumference, and contributes equally to the beauty and convenience of the province of Venezuela, with which it is encompassed. The water is used as a drink, though brackish and unwholesome. The gulph of this lake which terminates in the Caribbean Sea, extends about an hundred and ten miles from south to north.

[*Keysler, Addison, Coxe, Moore, Spalanzani, Swinburne, Casour, Clacigero, Swan, Payne.*

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3. *Particular Lakes; or such as are entitled to a more minute Description.*

Lake Asphaltites.

THIS is more usually known by the name of the *Dead Sea.* It lies in Palestine, and is about fifty miles long, and twelve or thirteen broad. It is surrounded by lofty mountains, and the river Jordan flows into it. It covers the old ground, that according to

Strabo's report, in consequence of an earthquake, accompanied by frequent eruptions of fire; or, according to the words of the Bible, in consequence of a rain of sulphur, buried the towns of Sodom and Gomorrha; and is very remarkable on account of the considerable proportion of salt which it contains. In this respect it surpasses every other known water on the surface of the earth. This great proportion of bitter-tasted salts is the reason why neither animal nor plant can live in this water: on which account the name of Dead Sea is applied to it with justice. This great proportion of salt gives to the water so great a specific gravity, that it is capable of bearing weights that would sink in the Ocean. Hence it happens that men, as Strabo long ago informed us, cannot dive in the Dead Sea, but are forcibly suspended on its surface.

The Dead Sea is farther remarkable on account of the great quantity of asphalt swimming on its surface, which having been originally thrown up from its bottom in a melted state by the agency of subterraneous heat, and being again solidified by the cold of the water, is at last collected on the margin of the lake, and forms an important article of traffic.

Two different sets of chemical experiments have already made us acquainted with the nature of the salts with which this water is impregnated.

The first of these is that of Macquer, Lavoisier, and Sage, inserted in the Memoirs of the Academy of Sciences for the year 1778, and entitled *Analyse de l'Eau du Lac Asphaltite*. Two flasks, sent by the Chevalier Tolesin Guettard, furnished the requisite quantity of water for this analysis.

They found the specific gravity of the water 1·240.

As the result of their analysis, they obtained from 5 pounds of the water 5 ounces of crystallized common salt, but not quite free from a small mixture of the salts with an earthy base. Farther, they obtained 30 ounces of earthy salts, consisting of four parts of muriate of magnesia, and three parts of muriate of lime. These proportions, reduced to 100 parts, give us the constituents of the salts of the Dead Sea as follows:

Muriate of magnesia	21·786
Muriate of lime	16·339
Muriate of soda	6·250
	44·375

The second analysis of this water has been published by Dr. Alexander Marcet, in the Philosophical Transactions for 1807, part 2d. The water examined by him, in company with Mr. Tennant, had been brought from the Dead Sea by Messrs. Gordon and Clunis during their Travels in the East, and had been sent by them to Sir Joseph Banks.

The specific gravity of this water was 1·211.

From 20 parts of the water there were obtained by evaporating in a sand-bath, at a temperature of 212° Fahrenheit, 7·7 parts of dry saline residue.

As the result of his analysis, he estimates the constituents in 100 parts of the water as follows:

Muriate of lime	3·791
Muriate of magnesia	10·100
Muriate of soda	10·376
Sulphate of lime	0·054
	24·622

Or, according to another mode of calculating,

Muriate of lime	3·920
Muriate of magnesia	10·246
Muriate of soda	10·360
Sulphate of lime	0·054
	24·580

This estimate does not, however, accord with the original statement, that 20 grains of water leave a residuum of 7·7 grains of dried salts. To make them agree, 100 grains must have furnished 38½ grains of salt.

This circumstance, together with the marked difference in the proportions of the salts, furnished by each analysis, induced me, says the former celebrated chemist, to undertake an analysis myself, having been furnished with a sufficient quantity of water for the purpose by Dr. William Thomson, whose recent death, at Palermo, has deprived mineralogy of a zealous disciple. This water had been brought by the Abbé Mariti from the East, and had been given by him to Dr. Targioni Tozzetti.

The water was colourless and transparent, except a small degree of muddiness, obviously owing to a cork-stopper. At the bottom of the flasks lay a single cubic crystal, which had again begun to re-dissolve. The taste of the water was bitter, saltish, and sharp. Its specific gravity was 1·245.

Five hundred grains of this water, evaporated to dryness and left upon a sand-bath till they no longer lost any weight, gave as a residue 213 grains of dry salt. This salt, while still warm, was digested with five times its weight of alcohol. After it had been allowed to exert its whole solvent power, by being left in a moderately warm place, and by frequent agitation, the alcohol was decanted off, and the undissolved salt treated again in the same manner with half the quantity of alcohol.

The alcohol was evaporated, and the residual dry salt was again treated with alcohol; but only with a quantity sufficient to take up the most soluble salts, and to separate a portion of common salt which had been dissolved along with them by the alcohol in the first process. The alcohol, being evaporated, left behind 174 grains of a salt mass, consisting of a mixture of muriate of magnesia and muriate of lime.

To determine the proportions of these two salts, the mass was dissolved in water, and precipitated while boiling by carbonate of soda. The edulcorated precipitate was mixed with water, saturated with sulphuric acid, and the liquor was evaporated to dryness. By washing the dry mass with a little water, the sulphate of magnesia was separated from the sulphate of lime, and the magnesia was precipitated at a boiling temperature by carbonate of soda. The precipitated magnesia, which when edulcorated and dried weighed 70 grains, was neutralized with muriatic acid, and the solution evaporated to dryness. The muriate of magnesia, thus restored, was found to weigh, while still warm, 121 grains. By subtracting this quantity from the original 179 grains, we obtain 53 grains as the weight of the muriate of lime.

The muriate of soda, freed by means of alcohol from the salts soluble in that liquid, weighed, after being well dried, 38 grains. But we may reckon 39 grains, the grain of difference wanting to make up the sum total of the salts, being obviously owing to the greater degree of dryness given in the last processes than in the first. The muriate of soda was dissolved in water, and tried with

carbonate of soda and muriate of barytes. No precipitation ensued; a proof that it contained no sulphate of lime.

In 100 parts of the water brought by the Abbé Mariti from the lake of Asphaltum, or Dead Sea, and examined by me, there were contained, therefore,

Muriate of magnesia	24·20
Muriate of lime	10·60
Muriate of soda	7·80
	42·60

The result of these experiments approaches that of Macquer, Lavoisier, and Sage. But the analysis of Dr. Marcet is a good deal different, owing in all probability to the complicated processes and calculations which he followed.

The specific gravity of the water, as stated by the French chemists, agrees likewise very nearly with mine. The sum of the saline ingredients, as stated by these gentlemen, exceeds what I obtained by 1¾ grains. This was probably owing to their being in a less degree of dryness; for it is well known, that the two earthy muriates absorb water from the atmosphere while cooling.

The somewhat smaller specific gravity found by Dr. Marcet renders it probable that the water which he examined was collected not far from the place where one of the streams of the river Jordan falls into the Dead Sea.

To give an example of the difference of the ingredients of this water from those of the ocean, I make choice of the specimen of sea-water which Sparrman drew in the month of July, 1776, in the latitude of the Canary Islands, from a depth of 60 fathoms, and which Bergman analysed. He found its specific gravity 1·0289; and a Swedish kanne = 100 Swedish cubic inches gave him

Muriate of soda	1393 grains
Muriate of magnesia	380
Sulphate of lime	45
	1818*

* Bergman's Opusc. vol. i p. 181.

The principal difference between the water of the ocean and that of the Dead Sea, consists in this remarkable circumstance, that in the latter the earthy muriates, which give the water its great sharpness and bitterness, exceed the proportion of common salt $4\frac{1}{2}$ times; while, on the contrary, the common salt exceeds the others nearly as much in the water of the ocean.

[*Thomson's Annals of Philosophy, Vol. I.*]

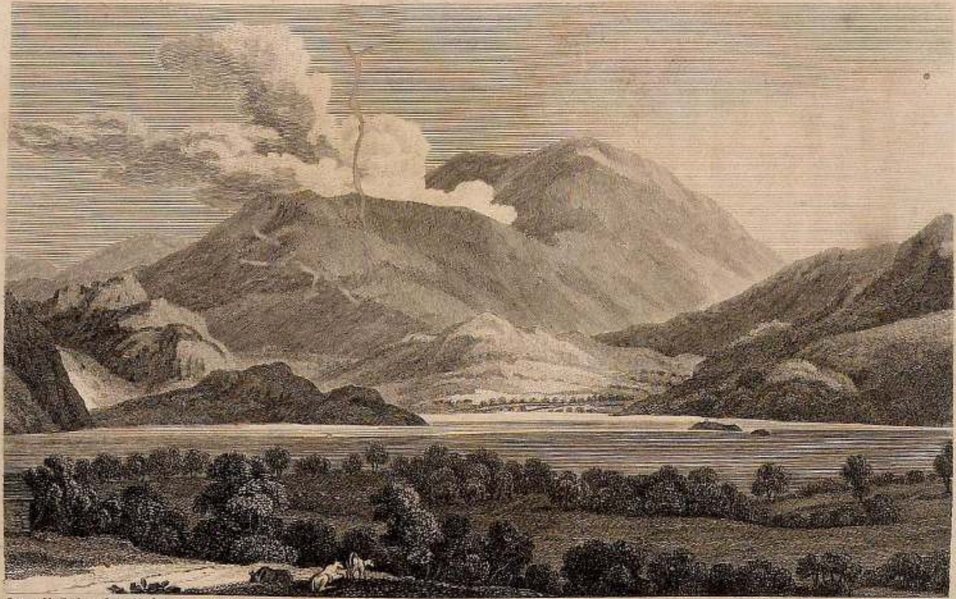
Ulswater Lake, and the surrounding Scenery.

From Mr. Gray to Dr. Wharton

Aston, Oct. 18, 1769.

I HOPE you got safe and well home after that troublesome night. I long to hear you say so. For me, I have continued well, been so favoured by the weather, that my walks have never once been hindered till yesterday (that is a fortnight and three or four days, and a journey of more than 300 miles). I am now at Aston for two days. To-morrow I go to Cambridge. Mason is not here, but Mr. Alderson receives me. According to my promise I send you the first sheet of my journal, to be continued without end.

Sept. 30. A mile and and a half from Brough, where we parted, on a hill lay a great army encamped: to the left opened a fine valley with green meadows and hedge-rows, a gentleman's house peeping forth from a grove of old trees. On a nearer approach appeared myriads of cattle and horses in the road itself, and in all the fields round me, a brisk stream hurrying cross the way, thousands of clean healthy people in their best party-coloured apparel: farmers and their families, esquires and their daughters, hastening up from the dales and down the fells from every quarter, glittering in the sun, and pressing forward to join the throng. While the dark hills, on whose tops the mists were yet hanging, served as a contrast to this gay and moving scene, which continued for near two miles more along the road, and the croud (coming towards it) reached on as far as Appleby. On the ascent of the hill above Appleby the thick hanging wood, and the long reaches of the Eden, clear, rapid, and as full as ever, winding below, with views of the castle and town, gave much employment to the mirror: but now the sun was wanting, and the sky overcast. Oats and barley cut every where, but not carried in. Passed Kirbythore, Sir William Dalston's house at Acorn-Bank, Whinfield Park, Harthorn Oaks, Countess-Pillar,



Engraved by Hay from a Drawing by Craig — *For the Gallery of Nature & Art*

ULLESWATER, WESTMORELAND.

From the Duke of Norfolk's Park.

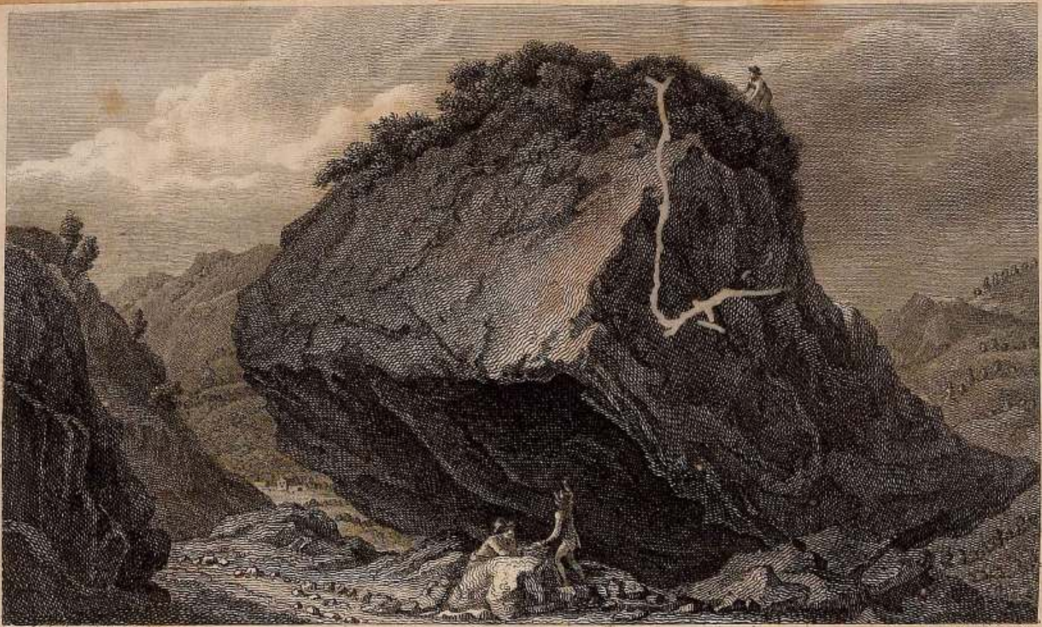
Brougham-Castle, Mr. Brown's large new house; crossed the Eden and the Eimot (pronounce Eeman) with its green vale, and dined at three o'clock with Mrs. Buchanan at Penrith, on trout and partridge. In the afternoon walked up Beacon-hill, a mile to the top, and could see Ulswater through an opening in the bosom of that cluster of broken mountains, which the doctor well remembers, Whinfield and Lowther Parks, &c. and the craggy tops of an hundred nameless hills: these lie to the west and south. To the north a great extent of black and dreary plains. To the east, Cross-fell, just visible through mists and vapours hovering round it.

Oct. 1. A grey autumnal day, the air perfectly calm and mild, went to see Ulswater, five miles distant; soon left the Keswick-road, and turned to the left through shady lanes along the vale of Eeman, which runs rapidly on near the way, ripling over the stones; to the right is Delmaine, a large fabric of pale red stone, with nine windows in front and seven on the side, built by Mr. Hassle, behind it a fine lawn surrounded by woods, and a long rocky eminence rising over them: a clear and brisk rivulet runs by the house to join the Eeman, whose course is in sight and at a small distance. Farther on appears Hatton St. John, a castle-like old mansion of Mr. Huddleston. Approached Dunmallert, a fine pointed hill covered with wood, planted by old Mr. Hassle before-mentioned, who lives always at home, and delights in planting. Walked over a spungy meadow or two, and began to mount the hill through a broad straight green alley among the trees, and with some toil gained the summit. From hence saw the lake opening directly at my feet, majestic in its calmness, clear and smooth as a blue mirror, with winding shores and low points of land covered with green inclosures, white farm-houses looking out among the trees, and cattle feeding. The water is almost every where bordered with cultivated lands, gently sloping upwards from a mile to a quarter of a mile in breadth, till they reach the feet of the mountains, which rise very rude and awful with their broken tops on either hand. Directly in front, at better than three miles distance, Place-Fell, one of the bravest among them, pushes its bold broad breast into the midst of the lake, and forces it to alter its course, forming first a large bay to the left, and then bending to the right. I descended Dunmallert again by a side avenue, that was only not perpendicular, and came to Barton-bridge over the Eeman, then walking through a path in

the wood round the bottom of the hill, came forth where the Eeman issues out of the lake, and continued my way along its western shore close to the water, and generally on a level with it. Saw a cormorant flying over it and fishing. The figure of the lake nothing resembles that laid down in our maps: it is nine miles long; and at widest under a mile in breadth. After extending itself three miles and a half in a line to the south-west, it turns at the foot of Place-Fell almost due west, and is here not twice the breadth of the Thames at London. It is soon again interrupted by the root of Hevellyn, a lofty and very rugged mountain, and spreading again turns off to south-east, and is lost among the deep recesses of the hills. To this second turning I pursued my way about four miles along its borders beyond a village scattered among trees, and called Water-Mallock, in a pleasant grave day, perfectly calm and warm, but without a gleam of sunshine: then the sky seeming to thicken, and the valley to grow more desolate, and evening drawing on, I returned by the way I came to Penrith.

Oct. 2. I set out at ten for Keswick, by the road we went in 1767; saw Graystock town and castle to the right, which lie about three miles from Ulswater over the fells; passed through Penradoch and Threlcot at the foot of Saddleback, whose furrowed sides were gilt by the noon-day sun, whilst its brow appeared of a sad purple from the shadow of the clouds as they sailed slowly by it. The broad and green valley of Gardies and Lowside, with a swift stream glittering among the cottages and meadows, lay to the left, and the much finer but narrower valley of St. John's opening into it: Hill-top, the large though low mansion of the Gaskarths, now a farm-house, seated on an eminence among woods, under a steep fell, was what appeared the most conspicuous, and beside it a great rock, like some ancient tower nodding to its fall. Passed by the side of Skiddaw and its cub called Latter-rig; and saw from an eminence, at two miles distance, the vale of Elysium in all its verdure; the sun then playing on the bosom of the lake, and lighting up all the mountains with its lustre. Dined by two o'clock at the Queen's Head, and then straggled out alone to the Parsonage, where I saw the sun set in all its glory.

Oct 3. A heavenly day; rose at seven and walked out under the conduct of my landlord to Borrowdale; the grass was covered with a hoar-frost, which soon melted and exhaled in a thin bluish smoke;



Engraved by Angus from a Drawing by Craig

For the Gallery of Nature & Art

BOWDAR STONE,

in the Gorge of Burrowdale, Cumberland.

crossed the meadows, obliquely catching a diversity of views among the hills over the lake and islands, and changing prospect at every ten paces. Left Cockshut (which we formerly mounted) and Castle-hill, a loftier and more rugged hill behind me, and drew near the foot of Walla-crag, whose bare and rocky brow cut perpendicularly down above four hundred feet (as I guess, though the people call it much more) awfully overlooks the way. Our path here tends to the left, and the ground gently rising and covered with a glade of scattering trees and bushes on the very margin of the water, opens both ways the most delicious view that my eyes ever beheld; opposite are the thick woods of Lord Egremont and Newland-valley, with green and smiling fields embosomed in the dark cliffs; to the left the jaws of Borrowdale, with that turbulent chaos of mountain behind mountain, rolled in confusion; beneath you, and stretching far away to the right, the shining purity of the lake reflecting rocks, woods, fields, and inverted tops of hills, just ruffled by the breeze, enough to shew it is alive, with the white buildings of Keswick, Crosthwaite church, and Skiddaw for a back-ground at a distance. Behind you the magnificent heights of Walla-crag: here the glass played its part divinely, the place is called Carfclose-reeds; and I chose to set down those barbarous names, that any body may inquire on the place, and easily find the particular station that I mean. This scene continues to Barrow-gate; and a little farther, passing a brook called Barrow-beck, we entered Borrowdale: the crags named Lawdoor-banks begin now to impend terribly over your way, and more terribly when you hear that three years since an immense mass of rock tumbled at once from the brow, and barred all access to the dale (for this is the only road) till they could work their way through it. Luckily no one was passing at the time of this fall; but down the side of the mountain, and far into the lake, lie dispersed the huge fragments of this ruin in all shapes and in all directions; something farther we turned aside into a coppice, ascending a little in front of Lawdoor water-fall; the height appeared to be about two hundred feet, the quantity of water not great, though (these three days excepted) it had rained daily in the hills for near two months before; but then the stream was nobly broken, leaping from rock to rock, and foaming with fury. On one side a towering crag that spired up to equal, if not overtop, the neighbouring cliffs (this lay all in shade and darkness): on the other hand a rounder

broader projecting hill shagged with wood, and illuminated by the sun, which glanced sideways on the upper part of the cataract. The force of the water wearing a deep channel in the ground, hurries away to join the lake. We descended again, and passed the stream over a rude bridge. Soon after we came under Gowdar-crag, a hill more formidable to the eye, and to the apprehension, than that of Lawdoor; the rocks at top deep-cloven perpendicularly, by the rains, hanging loose and nodding forwards, seem just starting from their base in shivers. The whole way down, and the road on both sides is strewed with piles of the fragments strangely thrown across each other, and of a dreadful bulk; the place reminds me of those passes in the Alps, where the guides tell you to move on with speed, and say nothing, lest the agitation of the air should loosen the snows above, and bring down a mass that would overwhelm a caravan. I took their counsel here, and hastened on in silence.

Non ragioniam di lor, ma guarda, e passa!

The hills here are clothed all up their steep sides with oak, ash, birch, holly, &c. some of it has been cut forty years ago, some within these eight years; yet all is sprung again, green, flourishing, and tall, for its age, in a place where no soil appears but the staring rock, and where a man could scarce stand upright: here we met a civil young farmer overseeing his reapers (for it is now oat-harvest) who conducted us to a neat white house in the village of Grange, which is built on a rising ground in the midst of a valley; round it the mountains form an awful amphitheatre, and through it obliquely runs the Derwent clear as glass, and shewing under its bridge every trout that passes. Beside the village rises a round eminence of rock covered entirely with old trees, and over that more proudly towers Castle-crag, invested also with wood on its sides, and bearing on its naked top some traces of a fort said to be Roman. By the side of this hill, which almost blocks up the way, the valley turns to the left, and contracts its dimensions till there is hardly any road but the rocky bed of the river. The wood of the mountains increases, and their summits grow loftier to the eye, and of more fantastic forms; among them appear Eagle's-cliff, Dove's-nest, Whitedale-pike, &c. celebrated names in the annals of Keswick. The dale opens about four miles higher till you come to Seawhaite (where lies the way mounting the hills to the right that leads to the Wadd-mines); all farther access is here barred to pry-

ing mortals, only there is a little path winding over the fells, and for some weeks in the year passable to the dalesmen; but the mountains know well that these innocent people will not reveal the mysteries of their ancient kingdom, "the reign of Chaos and Old Night;" only I learned that this dreadful road, dividing again, leads one branch to Ravenglas, and the other to Hawkshead.

For me I went no farther than the farmer's (better than four miles from Keswick) at Grange; his mother and he brought us butter that Siserah would have jumped at, though not in a lordly dish, bowls of milk, thin oaten-cakes, and ale; and we had carried a cold tongue thither with us. Our farmer was himself the man, that last year plundered the eagle's eyrie; all the dale are up in arms on such an occasion, for they lose abundance of lambs yearly, not to mention hares, partridges, grouse, &c. He was let down from the cliff in ropes to the shelf of the rock on which the nest was built, the people above shouting and hollowing to fright the old birds, which flew screaming round, but did not dare to attack him. He brought off the eaglet (for there is rarely more than one) and an addle egg. The nest was roundish, and more than a yard over, made of twigs twisted together. Seldom a year passes but they take the brood or eggs, and sometimes they shoot one, sometimes the other, parent; but the survivor has always found a mate (probably in Ireland) and they breed near the old place. By his description I learn, that this species is the *erne*, the vulture *albicilla* of Linnéus, in his last edition (but in yours *falco albicilla*), so consult him and Pennant about it.

We returned leisurely home the way we came; but saw a new landscape; the features indeed were the same in part, but many new ones were disclosed by the mid-day sun, and the tints were entirely changed; take notice this was the best, or perhaps the only day for going up Skiddaw, but I thought it better employed; it was perfectly serene, and hot as midsummer.

In the evening I walked alone down to the lake by the side of Crow-park after sunset, and saw the solemn colouring of night draw on, the last gleam of sunshine fading away on the hill-tops, the deep serene of the waters, and the long shadows of the mountains thrown across them, till they nearly touched the hithermost shore. At a distance were heard the murmurs of many water-falls, not audible in the

day-time; I wished for the moon, but she was *dark to me and silent,*

Hid in her vacant interlunar cave.

Oct. 4. I walked to Crow-park, now a rough pasture, once a glade of ancient oaks, whose large roots still remain on the ground, but nothing has sprung from them. If one single tree had remained, this would have been an unparalleled spot; and Smith judged right, when he took his print of the lake from hence, for it is a gentle eminence, not too high, on the very margin of the water, and commanding it from end to end, looking full into the gorge of Borrowdale. I prefer it even to Cockshut-hill which lies beside it, and to which I walked in the afternoon; it is covered with young trees both sown and planted, oak, spruce, Scotch-fir, &c. all which thrive wonderfully. There is an easy ascent to the top, and the view far preferable to that on Castle-hill (which you remember) because this is lower and nearer to the lake: for I find all points, that are much elevated, spoil the beauty of the valley, and make its parts, which are not large, look poor and diminutive. While I was here a little shower fell, red clouds came marching up the hills from the east, and part of a bright rainbow seemed to rise along the side of Castle-hill.

From hence I got to the Parsonage a little before sun-set, and saw in my glass a picture, that if I could transmit to you, and fix it in all the softness of its living colours, would fairly sell for a thousand pounds. This is the sweetest scene I can yet discover in point of pastoral beauty; the rest are in a sublimer style.

Oct. 5. I walked through the meadows and corn-fields to the Derwent, and crossing it went up How-hill; it looks along Bassingthwait-water, and sees at the same time the course of the river, and a part of the upper-lake, with a full view of Skiddaw; then I took my way through Portingskall village to the Park, a hill so called, covered entirely with wood; it is all a mass of crumbling slate. Passed round its foot between the trees and the edge of the water, and came to a peninsula that juts out into the lake, and looks along it both ways; in front rises Walla-crag and Castle-hill, the town, the road to Penrith, Skiddaw, and Saddleback. Returning, met a a brisk and cold north-eastern blast that ruffled all the surface of the lake, and made it rise in little waves that broke at the foot of

the wood. After dinner walked up the Penrith road two miles, or more, and turning into a corn-field to the right, called Castle-rig, saw a Druid-circle of large stones, 108 feet in diameter, the biggest not eight feet high, but most of them still erect; they are fifty in number. The valley of St. John's appeared in sight, and the summits of Catchidecam (called by Camden, Casticand) and Helvellyn, said to be as high as Skiddaw, and to rise from a much higher base.

Oct. 6. Went in a chaise eight miles along the east side of Bassingthwait-water to Ousebridge (pronounced Ews-bridge); the road in some part made and very good, the rest slippery and dangerous cart-road, or narrow and rugged lanes, but no precipices; it runs directly along the foot of Skiddaw; opposite to Widhope-brows, cloathed to the top with wood, a very beautiful view opens down to the lake, which is narrower and longer than that of Keswick, less broken into bays, and without islands. At the foot of it, a few paces from the brink, gently sloping upwards, stands Armathwaite in a thick grove of Scotch firs, commanding a noble view directly up the lake: at a small distance behind the house is a large extent of wood, and still behind this a ridge of cultivated hills, on which, according to the Keswick proverb, *the sun always shines*. The inhabitants here, on the contrary, call the vale of Derwent-water, *the Devil's Chamber-pot*, and pronounce the name of *Skiddaw-fall*, which terminates here, with a sort of terror and aversion. Armathwaite house is a modern fabric, not large, and built of dark-red stone, belonging to Mr. Spedding, whose grandfather was steward to old Sir James Lowther, and bought this estate of the Himers. The sky was overcast and the wind cool; so, after dining at a public-house, which stands here near the bridge, (that crosses the Derwent just where it issues from the lake) and sauntering a little by the water-side I came home again. The turnpike is finished from Cockermouth hither, five miles, and is carrying on to Penrith: several little showers to-day. A man came in, who said there was snow on Cross-fell this morning.

Oct. 7. I walked in the morning to Crow park, and in the evening up Penrith road The clouds came rolling up the mountains all round very dark, yet the moon shone at intervals. It was too damp to go towards the lake. To-morrow I mean to bid farewell to Keswick.

Botany might be studied here to great advantage at another season, because of the great variety of soils and elevations, all lying within a small compass. I observed nothing but several curious lichens, and plenty of gale or Dutch myrtle perfuming the borders of the lake. This year the Wadd-mine had been opened, which is done once in five years; it is taken out in lumps sometimes as big as a man's fist, and wlll undergo no preparation by fire, not being fusible; when it is pure, soft, black, and close-grained, it is worth sometimes thirty shillings a pound. There are no char ever taken in these lakes, but plenty in Butter-mere-water, which lies a little way north of Borrowdale, about Martinmas, which are potted here. They sow chiefly oats and bigg here, which are now cutting and still on the ground; the rains have done much hurt: yet observe, the soil is so thin and light, that no day has passed in which I could not walk out with ease, and you know I am no lover of dirt. Fell mutton is now in season for about six weeks; it grows fat on the mountains, and nearly resembles venison. Excellent pike and perch, here called Bass; trout is out of season; partridge in great plenty.

Oct. 8. I left Keswick and took the Ambleside road in a gloomy morning; and about two miles from the town mounted an eminence called Castle-rigg, and the sun breaking out, discovered the most enchanting view I have yet seen of the whole valley behind me, the two lakes, the river, the mountains, all in their glory; so that I had almost a mind to have gone back again. The road in some few parts is not yet compleated, yet good country road, through sound but narrow and stony lanes, very safe in broad daylight. This is the case about Causeway-foot, and among Naddle-fells in Lancwaite. The vale you go in has little breadth; the mountains are vast and rocky, the fields little and poor, and the inhabitants are now making hay, and see not the sun by two hours in a day so long as at Keswick. Came to the foot of Helvellyn, along which runs an excellent road, looking down from a little height on Lee's water, (called also Thirl-meer, or Wiborn-water) and soon descending on its margin. The lake looks black from its depth, and from the gloom of the vast crags that scowl over it, though really clear as glass; it is narrow, and about three miles long, resembling a river in its course; little shining torrents hurry down the rocks to join it, but not a bush to overshadow them, or cover their march;

all is rock or loose stones up to the very brow, which lies so near your way, that not above half the height of Helvellyn can be seen.

Next I passed by the little chapel of Wiborn, out of which the Sunday congregation were then issuing; soon after a beck near Dunmeil-raise, when I entered Westmoreland a second time; and now began to see Holmcrag, distinguished from its rugged neighbours, not so much by its height as by the strange broken outlines of its top, like some gigantic building demolished, and the stones that composed it flung across each other in wild confusion. Just beyond it opens one of the sweetest landscaps that art ever attempted to imitate. The bosom of the mountains spreading here into a broad bason discovers in the midst Grasmere-water; its margin is hollowed into small bays, with bold eminences; some of rock, some of soft turf, that half-concealed, and vary the figure of the little lake they command: from the shore, a low promontory pushes itself far into the water, and on it stands a white village with the parish church rising in the midst of it: hanging inclosures, corn-fields, and meadows green as an emerald, with their trees and hedges, and cattle, fill up the whole space from the edge of the water; and just opposite to you is a large farm-house at the bottom of a steep smooth lawn, embosomed in old woods, which climb half-way up the mountain's side, and discover above them a broken line of crags that crown the scene. Not a single red tile, no flaring gentleman's house, or garden-walls, break in upon the repose of this little unsuspected paradise; but all is peace, rusticity, and happy poverty in its neatest most becoming attire.

The road winds here over Grasmere-hill, whose rocks soon conceal the water from your sight; yet it is continued along behind them, and, contracting itself to a river, communicates with Ridale-water, another small lake, but of inferior size and beauty; it seems shallow too, for large patches of reeds appear pretty far within it. Into this vale the road descends. On the opposite banks large and ancient woods mount up the hills; and just to the left of our way stands Ridale-hall, the family seat of Sir Michael Fleming, a large old-fashioned fabric, snrrounded with wood. Sir Michael is now on his travels, and all this timber, far and wide, belongs to him. Near the house rises a huge crag, called Ridale-head, which is said to command a full view of Wynander-mere, and I doubt it

not; for within a mile that great lake is visible, even from the road; as to going up the crag, one might as well go up Skiddaw.

I now reached Ambleside, eighteen miles from Keswick, meaning to lie there; but, on looking into the best bed-chamber, dark and damp as a cellar, grew delicate, gave up Wynander-mere in despair, and resolved I would go on to Kendal directly, fourteen miles farther. The road in general fine turnpike, but some parts (about three miles in all) not made, yet without danger.

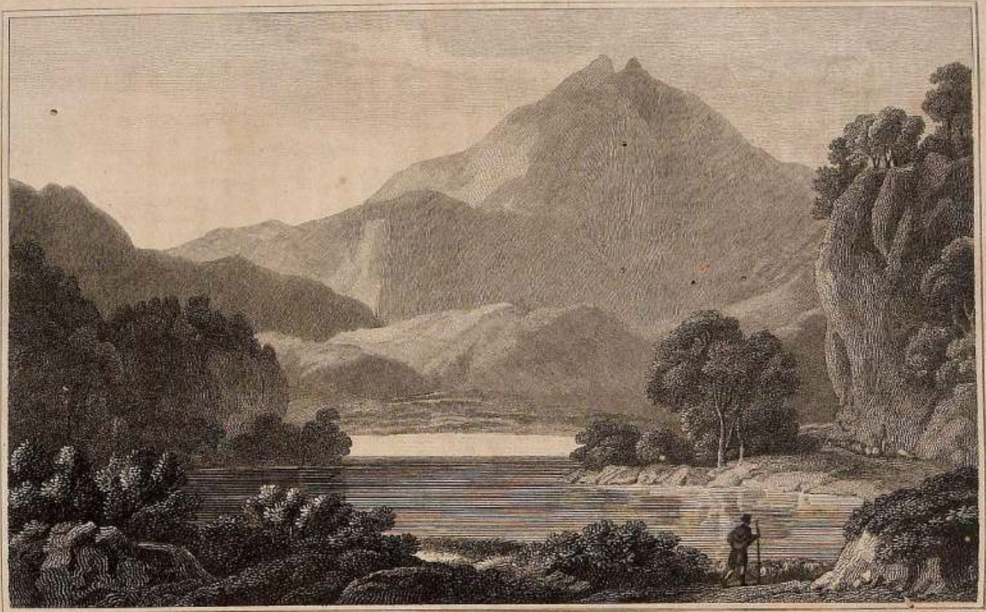
For this determination I was unexpectedly well rewarded: for the afternoon was fine, and the road, for the space of full five miles, ran along the side of Wynander-mere, with delicious views across it, and almost from one end to the other. It is ten miles in length, and at most a mile over, resembling the course of some vast and magnificent river; but no flat marshy grounds, no osier-beds, or patches of scrubby plantations on its banks: at the head two vallies open among the mountains; one, that by which we came down, the other Langsledale, in which Wry-nose and Hard-knot, two great mountains, rise above the rest: from thence the fells visibly sink, and soften along its sides; sometimes they run into it (but with a gentle declivity) in their own dark and natural complexion: oftener they are green and cultivated, with farms interspersed, and round eminences, on the border covered with trees: toward the south it seemed to break into large bays, with several islands and a wider extent of cultivation. The way rises continually, till at a place called Orrest-head it turns south-east, losing sight of the water.

[*Mason's edit. of Gray's Works.*

Loch-Lomond, and the adjoining Lakes.

North-Britain may well boast of its waters; for so short a ride as thirty miles presents the traveller with the view of four most magnificent pieces. Loch-Aw, Loch-Fine, Loch-Long, and Loch-Lomond. Two indeed are of salt-water; but, by their narrowness, give the idea of fresh water lakes. It is an idle observation of travellers, that seeing one is the same with seeing all of these superb waters; for almost every one I visited has its proper characters.

Loch-Leven is a broad expanse, with isles and cultivated shores.



Engraved by Lacey, from a Drawing by Daly

For the Gallery of Nature & Art

LOCH-LOMOND, AND BEN-LOMOND.

London, Published by R. Wilks, 89 Chancery Lane, Aug 1 1810.

Loch-Tay makes three bold windings, has steep but sloping shores, cultivated in many parts, and bounded by vast hills.

Loch-Rannoch is broad and strait, has more wildness about it, with a large natural pine wood on its southern banks.

Loch-Tumel is narrow, confined by the sloping sides of steep hills, and has on its western limits, a flat, rich, wooded country, watered by a most serpentine stream.

The Loch of Spinie is almost on a flat, and its sides much indented.

Loch-Moy is small, and has soft features on its banks, amidst rude environs.

Loch-Ness is strait and narrow: its shores abound with a wild magnificence, lofty, precipitous and wooded, and has all the greatness of an Alpine lake.

Loch-Oich has lofty mountains at a small distance from its borders; the shores indented, and the water decorated with isles.

Loch-Loch wants the isles; its shores slope, and several straiths terminate on its banks.

Loch-Aw is long and waving: its little isles tufted with trees, and just appearing above the water, its two great feeds of water at each extremity, and its singular lateral discharge near one of them, sufficiently mark this great lake.

Loch-Lomond, the last the most beautiful of the Caledonian lakes. The first view of it from Tarbat presents an extensive serpentine winding amidst lofty hills: on the north, barren, black and rocky, which darken with their shade that contracted part of the water. Near this gloomy tract, beneath craig Roston, was the principal seat of the M'Gregors, a murderous clan, infamous for excesses of all kinds; at length, for a horrible massacre of the Colquhouns, or Cahouns, were proscribed, and hunted down like wild beasts; their very name suppressed by act of council; so that the remnant, now dispersed like Jews, dare not even sign it to any deed. Their posterity are still said to be distinguished among the clans in which they have incorporated themselves, not only by the redness of their hair, but by their still retaining the mischievous dispositions of their ancestors.

On the west side, the mountains are clothed near the bottoms with woods of oak quite to the water edge; their summits lofty, naked and craggy.

On the east side, the mountains are equally high, but the tops form a more even ridge parallel to the lake, except where Ben-Lomond, like Saul amidst his companions, overtops the rest. The upper parts were black and barren; the lower had great marks of fertility, or at least of industry, for the yellow corn was finely contrasted with the verdure of the groves intermixed with it.

This eastern boundary is part of the Grampian hills, which extend from hence through the counties of Perth, Angus, Mearns, and Aberdeen. They take their name from only a single hill, the Mons Grampius of Tacitus, where Galgacus waited the approach of Agricola, and where the battle was fought so fatal to the brave Caledonians. Antiquarians have not agreed upon the particular spot; but Mr. Gordon places it near Comrie, at the upper end of Strathern, at a place to this day called *Galgachan Moor.* But to return.

The road runs sometimes through woods, at others is exposed and naked; in some, so steep as to require the support of a wall: the whole work of the soldiery: blessed exchange of instruments of destruction for those that give safety to the traveller, and a polish to the once inaccessible native.

Two great headlands covered with trees separate the first scene from one totally different; the last is called the Point of Firkin. On passing this cape an expanse of water bursts at once on your eye, varied with all the softer beauties of nature. Immediately beneath is a flat covered with wood and corn: beyond, the headlands stretch far into the water, and consist of gentle risings; many have their surfaces covered with wood, others adorned with trees loosely scattered either over a fine verdure, or the purple bloom of the heath. Numbers of islands are dispersed over the lake of the same elevated form as the little capes, and wooded in the same manner; others just peep above the surface, and are tufted with trees; and numbers are so disposed as to form magnificent vistos between.

Opposite Luss, at a small distance from shore, is a mountainous isle almost covered with wood; is near half a mile long, and has a most fine effect. I could not count the number of islands, but was told there are twenty-eight: the largest two miles long, and stocked with deer.

The length of this charming lake is 24 Scotch miles; its greatest

Engraved by [illegible] from a Drawing by [illegible]

For the Gallery of Nature & Art

THE PEES BRIDGE, BETWEEN BERWICK AND EDINBURGH.

London, Published by R. Wilks 89 Chancery Lane Jany [illegible]

breadth eight: its greatest depth, which is between the point of Firkin and Ben-Lomond, is a hundred and twenty fathoms. Besides the fish common to the lochs are Guiniads, called here Poans.

At this time were living at the little village of Luss the following persons, most amazing instances of cotemporary longevity; and perhaps proofs of the uncommon healthiness of the place. These compose the venerable list:

Rev. Mr. James Robertson, Minister, aged.... 90.
Mrs. Robertson, his wife.................. 86.
Anne Sharp, their servant, ... 94.
Niel Macnaughtan, Kirk officer, ... 86.
Christian Gay, his wife, ... 94.
Walter Maclellan, ... 90.

The country from Luss to the southern extremity of the lake continually improves; the mountains sink gradually into small hills; the land is highly cultivated, well planted, and well inhabited. I was struck with rapture at a sight so long new to me: it would have been without alloy, had it not been dashed with the uncertainty whether the mountain virtue, hospitality, would flourish with equal vigor in the softer scenes I was on the point of entering on; for in the Highlands every house gave welcome to the traveller.

On the road side near Luss is a quarry of most excellent slates; and near the side of the lake, about a mile or two farther, is a great heap of stones in memory of St. Mac-Kessog, Bishop and Confessor, who suffered martyrdom there A. D. 520, and was buried in Comstraddan church.

The vale between the end of the lake and Dumbarton is unspeakably beautiful, very fertile, and finely watered by the great and rapid river Lewin, the discharge of the lake, which, after a short course, drops into the Firth of Clyde below Dumbarton: there is scarcely a spot on its banks but what is decorated with bleacheries, plantations and *villas*. Nothing can equal the contrast in this day's journey, between the black barren dreary glens of the morning ride, and the soft scenes of the evening, islands worthy of the retreat of Armida, and which Rinaldo himself would have quitted with a sigh.

Before I take my last leave of the Highlands, it will be proper to observe that every entrance into them is strongly marked by nature.

On the south, the narrow and wooded glen near Dunkeld instantly shews the change of country.

On the east, the craggy pass of Bollitir gives a contracted admission into the Grampian hills.

On the north, the mountains near Loch-May appear very near, and form what is properly styled the threshold of the country; and on the west, the narrow road impending over Loch-Lomond forms a most characteristic entrance to this mountainous tract.

But the Erse or Galic language is not confined within these limits; for it is spoken on all sides beyond these mountains. On the eastern coast it begins at Nairn; on the western, extends over all the isles. It ceases in the north of Cathness, the Orkneys, and the Shetland islands; but near Loch-Lomond, is heard at Luss, at Buchanan, east of the lake, and at Roseneth, west of it.

The traveller, who has leisure, should ride to the eminence of Millegs, to see the rich prospect between Loch-Lomond and the Clyde. One way is seen part of the magnificent lake, Ben-Lomond and the vast mountains above Glen-Crow. On the other hand appears a fine reach of the Clyde enlivened with shipping, a view of the pretty seats of Roseneth and Ardincapel, and the busy towns of Port-Glasgow and Greenock.

[*Pennant's Tour in Scotland.*

Loch-Ness. By the Rev. Mr. James Fraser.

Loch Ness, according to our Highland tradition, took its name from Nisus, an Irish hero, who, with Dornadillo his wife, settled a colony in Stratharig. The promontory on which he had his residence is to this day called Doun Dearnill; and he being the first that ever offered to set out boat or barge upon this lake, it is after him called Loch-Ness. It is 24 miles in length, and in most parts two in breadth. In many parts of this lake it has been sounded, with more than 500 fathoms of line, but no bottom found. The banks of this lake are high and mountainous, with woods. The lake never freezes, which is imputed to the many great springs and fountains in it: the only fish in it is salmon. This lake discharges itself into a river of the same name, six miles in length, which never freezes, but always smokes with frost. On the north side

of Loch-Ness stands, on a rock, the famous castle of Urqhart; the great ditch round it was for the most part cut out of the rock, and received water from the lake. This castle consisted of seven great towers, and it is said was built by the Cuminees, or Cumings, but was demolished by King Edward the First of England, leaving only one tower to the east, still remaining. About four miles to the westward of this castle, on the side of Loch-Ness, stands that great mountain Meal-fuor-vouny, of a round shape, and very high, esteemed two miles of perpendicular height from the lake. On the very top of this hill is a lake of cold fresh water, about 30 fathoms in length, and six broad, no course or stream running either to it or from it. The bottom of it cannot be sounded. With 100 fathoms of small line I could find no bottom. It is always equally full, and never freezes.

There is, due west, from the end of the river Ness, an arm of the sea, called Beuly Frith, six miles in length and two in breadth. The bottom seems to have once been firm land, for near the middle of it are found long oak trees, with their roots entire, some above 60 feet in length, lying covered with the sand, which doubtless have grown there; there are also three great cairns or heaps of stones in this lake, at considerable distance from each other; one of a huge size, in the middle o[illegible]ssible at low water, and appears to have been a b[illegible] place, by the urns which are sometimes discovered. As the sea encroaches and wears the banks upward, there are found long oaken beams of 20 or 30 feet long, some of them 8, 12, or 14 feet under ground. I saw one of them 14 feet long, that had the mark of the axe on it, with several augre bores in it. The river Beuly, which falls into this arm of the sea, near Lovat, has sunk so low that oaken trees of great length, and 16 feet under ground, are discovered in the banks, with layers of sand, gravel, clay, and earth over them; and we have found some oaks, with coals, and pieces of burnt timber, as low as 16 feet deep.

About 17 miles due west from Beuly, there is a forest called Affaruck, in which there is a mountain called Glenin-tea, and on the north side, under the shade of a great sloping rock, stands a lake of fresh water, called Lochan Wyn, or Green Lake, 18 feet in diameter, about a fathom deep, which is always covered with ice, summer and winter. The next mountain, north of that, is

called Scúre-in-Lappich; on the top of which is a vast heap of white stones like crystal, each of them larger than a man can throw, which strike fire like flint, and have the smell of sea-weed. On this mountain are found also oyster, scallop, and limpet-shells, though ten miles from any sea. Round this hill grows the sea pink, in Irish, teartag, having the taste and colour of that which grows on the sea banks.

The Pagan temples, or high places of idolatry, are still very numerous here; on the river side of Narden I reckoned 13 in two miles: they are round, and at the west end have two high stones like pyramids; there is an outer and inner circle of lesser stones, and a round mote in the centre for the sacrifices. Another sort of them is only of earth, with a trench round about, and a mote in the middle. In many of these I find a round heap of stones with urns in them. It seems a different religion afterwards changed these places of worship into burial places.

[*Phil. Tran.* 1699.

Lough-Neagh.

Most of the ancient writers, who have treated of Ireland, have mentioned the peculiar qualities of Lough-neagh, of turning wood into stone; so [illegible] gone so far as to say, that it would turn that part of the w[illegible] which was in the mud into iron; the part in the water into stone, while the part above water remained wood.

Some later writers, particularly Wm. Molyneux, Francis Nevil, and Edward Smyth, and from them the late Dr. Woodward †, and others ‡, seem rather to think, that this petrifying quality does not lie so much in the lake itself, as in the ground near or about it.

Mr. Edward Smyth §, who enlarges most on this subject, and seems to have led the others, and drawn them into his opinion, tells us, "That no experiment or observation yet made, which he had heard of, could prove that this lough has really the quality of

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* Boetius Hist. Gem. et Lap.—Orig.

† Catal. of English Fossils, part 2, p. 19.—Orig.

‡ Sir James Ware's Antiq. by Walt. Harris, p. 227. edit. 1747, folio.—Orig.

§ Afterwards Bishop of Down. See Phil. Trans. No. 174.—Orig.

petrifying wood, or that the water does any way help or promote the petrification." He there gives an example of a gentleman of worth and credit, "who had fixed two stakes of holly in two different places of the lough, near that place where the upper-bann enters into it, and that the parts of the stakes which had been washed by the water for about nineteen years, yet remained there without any alteration, or the least advance to petrifaction."

Another reason for his doubting of this quality is, "That though it is reported that the water has this virtue, especially where the black-water discharges itself into the lake, yet that as it seems evident from the nature of liquid bodies, that any virtue received in one part must necessarily be diffused through the whole, at least in some degree; therefore, says he, there is good reason to believe, that the water is wholly destitute of this petrifying quality:" but a few lines lower he tells you, "That he had sufficient ground to conjecture, that other wood as well as holly had been petrified about this lough; because some fishermen, being tenants to a gentleman from whom he had this account, told him, that they had found buried, in the mud of this lough, large trees, with all their branches and roots petrified; and som[illegible] that they believed they could scarcely be drawn by a [illegible] they had broken off several branches as thick as a [illegible]s leg, and many thicker, but could not move the great trunk."

He supposes Mr. Smyth, or the gentleman his friend, saw these branches, and was thereby convinced of their real petrification, as he was by the bulk of those trees of their being oak, and not holly; "because, says he, no other tree in that country, these excepted, grows to that vast size; at least it is certain that holly never does."

But how Mr. Smyth came to be convinced, that these trees were oak, and not holly, and yet was not convinced of the petrific quality in some parts of the lough, though these trees were found petrified in its mud, is amazing; for if a team of oxen could scarcely draw them from thence, it must be as hard to draw them from any adjacent ground (where they must have grown, lain, and be petrified) into the mud of the lake, where they were afterwards found: for it must be supposed, that either these trees grew on the banks of the lake, and, through age, or any other accident, fell into the water or mud, and were there petrified; or that, with great labour

T 2

and expense, they were brought into it from some adjacent ground, after their actual petrification, which is hardly to be supposed.

Mr. Smyth tells you further, that "Two gentlemen of the north of Ireland where this lough lies, had told him, that they had seen the same body, partly wood, and partly stone; but the only reason for thinking so, being the diversity of colours, which might well enough proceed from several degrees of petrification, we may properly think them deceived; for they made no experiment on that part which they reputed wood. The bark is never found petrified, as he was informed by a diligent inquirer; but often somewhat rotten about the stone, answerable to the bark."

Mr. Smyth contradicts himself no less in his last supposition, than he did in the first. His friends assured him, that they had seen one or more of the Lough-neagh stones partly wood and partly stone; but they were deceived, he says: the diversity of colours, by which they judged one part of the stone by its colour to be wood, and the other part likewise, by its colour different from the other, to be stone, were no more than different degrees of petrification. What are we to understand by these different degrees of petrifaction? by this something rotten about the stone often found? if not, that some part of the wood was actually turned into stone, some other part in a degree less petrified, and some other part not petrified at all, as these gentlemen assured him: the diversity of colours, seeing and feeling, was enough to convince them, and to determine the point.

"The earth, says the great Robert Boyle *, harbours different kinds of petrescent liquors, and many of them impregnated with one sort of mineral or other." There are no springs, no waters, but are more or less impregnated with such mineral and saline particles; which appears from the most limpid; which after evaporation, still in the residuum, gives some particles of salt, with some stony and mineral ones.

Mr. Smyth has found by experience, that petrifying springs are generally impregnated, some with calcareous and particles of other stones, and others with ferrugineous and vitriolic particles. Those of the stony or calcareous kind, when they drop on wood, or other vegetables, act on them for the most part by incrustation, having different degrees and periods for their respective incrustations and

* R. Boyle, of the Origin and Virtues of Gems.—Orig.

coalitions, which yet adhere close to each other: they seldom turn the wood into stone; but, sticking to the wood, plants, &c. coagulate on it, and by degrees cover it with a crust of a whitish substance of different thickness, by which the wood is immerged or wrapped in a stony coat, which, if it be broken before the wood be rotten, you find it in the heart of the stone or incrustation, as is seen in those petrifications at Maudling meadows in Gloucestershire, at Hermitage near Dublin, and many other places: or, if the wood be rotten, you will find a cavity in the stone, which very often is filled by a subsequent incrustation or petrification; the stony particles then taking the place of the rotten wood.

Sometimes indeed, these waters, permeating the pores of the wood either longitudinally or transversely, insinuate themselves into them, fill them up with their stony particles, swell, and, by their burning or corroding quality proceeding from the lime-stone, destroy the wood, and assume the shape of the plant, the place of which they have taken.

These petrifications generally ferment with acids and spirit of vitriol, and by calcination may be reduced to lime.

Ferrugineous or metallic petrifying waters mostly act by insinuating their finest particles through the pores and vessels of the wood, or other vegetables, without increasing their bulk, or altering their texture, though they greatly increase their specific gravity: and such is the petrified wood found in or on the shores of Lough-neagh; for it does not show any outward addition or coalition of forcing matter adhering to, or covering it (except in some places, where a thin slimy substance, taken notice of hereafter, is sometimes observed,) but preserve the grain and vestigia of wood; all the alteration is in the weight and closeness, by the mineral particles pervading and filling the pores of the wood: these stones, or rather wood-stones, do not make the least effervescence with spirit or oil of vitriol, nor aquafortis; which shows that they are impregnated with métalline particles, or stony ones, different from the calcareous kind; and may be the reason why the petrified wood, mentioned by N. Grew *, made no ebullition, at which it seems he was surprised †. These stones he could not reduce into lime by the most

* Reg. Soc. Mus. p. 270.—Orig.

† This contradicts an observation of Mr. John Beaumont, (Phil. Trans. No. 129), That mostly mineral stones will stir with acids; whereas all those that I have tried, whether English or Irish, did not at all stir with acids.—Orig.

intense fire, nor, with proper ingredients, procure a vetrification or fusion*.

Though mines have not perhaps been discovered near the lough, there is reason to believe that there are such in its neighbourhood, from the great quantity of iron-stones found on its shores, and places adjacent to it, and from the yellowish ochre and clay to be met with in many places near it. Of these iron-stones, which are very ponderous, outwardly of an ocherish yellow colour, and inwardly of a reddish brown, he calcined many, and found the powder of all to yield strongly to the magnet. Gerald Boate † mentions an iron mine, in the county of Tyrone, not far from the lough, and such others at the foot of Slew-Gallen mountains.

That mines are generated and found in the bowels of hills and mountains, is obvious to any that have the least knowledge of metallurgy; and that springs also proceed from mountains, is no less obvious; therefore should a spring happen in the bowels of any of these mountains to run through a vein of mineral of any kind whatever, it will wash and dilute some parts of such mineral, impregnate itself with the unctuous, saline, and metallic particles of such mines, and convey them along with its water; and if in its way, whether under-ground, or at its issuing out of the cliffs of a mountain, of the sides of a river, or of the lake in question; or whether it rises under water, in the middle of such a river or lake in any particular place, and in its course meets with wood, vegetables, or any other lax bodies (lodged in the mud or gravel), whose pores, by the natural heat of the mineral streams, or any other accident, being open and duly prepared, these metallic moleculæ and saline particles will penetrate through, insinuate and lodge themselves in the pores and vessels of such wood, &c. fill them up, and, by degrees, turn them into stone ‡; "There being some of these lapidescent juices of so fine a substance, yet of so petrifying a virtue, that they will penetrate and petrify bodies of very different kinds, and yet scarcely, if at all, visibly increase their bulk, or change their shape and colour."

* Stones of the calcareous kind turn to lime by calcination, and ferment with acids; but other kinds, such as slate, fire-stone, free-stone, rag, grill, &c. will do neither, as experience has hitherto testified.—Orig.

† Nat. Hist. of Ireland, Dub. 1726.—Orig.

‡ Rob. Boyle of Gems, p. 124, 8vo.—Orig.

That such springs there are, hidden under the water or mud of this lake, will appear probable, from what has been said, and perhaps evident, from the accounts since received, that in the great frost of 1740, the lake was frozen over so as to bear men on horseback, yet several circular spaces continued unfrozen. But how several attempts, made, as mentioned, by Messrs. Molineux, Nevil, and Smyth, to procure wood half petrified (by fixing stakes of holly in the lake, which received no alteration) proved unsuccessful, the reason I think is plain, because they were not fixed in the proper place, viz. the course or vein of the spring, where nothing but chance could have directed them. This petrified wood is often found in different places on the shores of the lough, but generally in greater plenty when the water has been disturbed by great storms; which makes it impossible to fix on the particular place where the petrifying juice most prevails; except a tree, or any larger piece, should be found so fixed as to resist the force of the waves.

That this petrific quality is in some peculiar parts of the lake, he has endeavoured to prove; that it is or may be in some peculiar places of the adjacent ground, he grants; though as yet he could not procure any of those stones found in the ground, with wood continuous. Such as he has seen, are of the white whetstone kind, and seem to be holly or ash, petrified by some strong nitrous and stony particles: for, in a solution of it in aquafortis and oil of vitriol, it leaves no tincture, but the liquor growing muddy, like pipe-water after great rains, and therefore shows that they are not so strongly impregnated with metalline particles, as those stones found in or on the shores of the lake.

Mineral streams or exhalations, being highly saturated with stony and mineral particles, are often found to have a petrifying virtue, as is seen at the bath called Green Pillars * in the city of Buda in Hungary. If such streams should, in certain places, find or force their way through the sand or pores of the earth, they may operate on wood, &c. buried in the ground, permeate its vessels, and by degrees turn it into stone; and such is the most probable, if not the only reason, that can be assigned for those petrifications of wood found in sand, as mentioned by Boyle and Plot.

* Philos. Trans. No. 59.—Orig.

He received last summer, 1745, from a friend about thirty of these stones, found on the shores of the lake, some in the water, some in the mud, some in the sand, and others in a yellowish clay. That they were petrified in the lake is probable, but whether in the water, mud, sand, or clay, is no matter; for certain it is (to use Mr. Smyth's own words), that they were not brought hither from any distance, such as 2, 4, 6, 8 miles, after being dug out of the ground, and then thrown and dispersed on the shores of the lake: and besides, the difference in the colour of these stones, those found in the lake, and those found in the ground somewhat distant from it, is such that they cannot well be mistaken for each other. Those found in the ground are white, and of a looser texture; those found in or on the shores of the lake are black, closer, and heavier. That these last were petrified by a mineral spring, appears from the few following observations.—They do not ferment with acids, spirit and oil of vitriol. The solution of this stone in aquafortis gives a beautiful red tincture; and in oil of vitriol leaves a tincture of a brown dark red. The woody part of these stones in aquafortis also gives a red tincture, though somewhat paler; and, when taken out of the liquor, shows red spots in its pores, which he takes to be particles of iron and sulphur: these spots, when the wood began to dry, became black; and the wood, when dry, turned of the colour of a deep red Jesuit's-bark.

In some of these stones, several curious veins, of a red and bluish colour are very remarkable, being intermixed with black and white striæ. Having broken some of them, he found in the inside a kind of white, and several clusters of small white and black angular crystals, which through the microscope appear transparent, and of different shapes, but mostly hexagonal. He discovered such crystals in some of the woody part of these stones.

One piece of a white stone he calcined in a crucible for twenty-four hours, but could neither reduce it to coal nor lime. The powder yielded faintly to the magnet. This stone was found in the ground at some distance from the lake. One piece of a black stone, found in the lake, he likewise calcined for twenty-four hours, and could not reduce it to coal or lime: the powder yielded briskly to the magnet. He calcined one piece of another stone, about one inch thick, for about four hours, in an intense fire, till it grew as red as it could be, when he took it out of the crucible. He observed

several veins, not discernible before, of a ferruginous matter, about $\frac{1}{10}$ of an inch thick, and when reduced to powder, it applied strongly to the magnet.

In other stones he found some veins of wood, about one and two inches thick, no way petrified, though the stones were every where so outwardly. Some of that woody part he also burnt in a crucible; it emitted a bluish flame, as if impregnated with sulphur, and had the strong smell of burning charcoal. When burnt to a coal, and reduced into powder, it faintly yielded to the magnet.

He calcined another of these stones, weighing 1 oz. 13 dwts. $12\frac{1}{2}$ gr.; after burning four hours it weighed only 1 oz. 10 dwts. $8\frac{1}{4}$ gr. which lost 3 dwts. 4 gr.; which proceeds probably from unpetrified veins of wood in the heart of the stone, which were destroyed by the fire, as in the crucible it emitted now and then a bluish flame, like brandy when burning. This stone, when taken out of the crucible, and cooled, had the colour of iron, when heated in, and cooled from the forge.

Part of another stone, which by visible veins of ore, appeared to contain a good deal of iron, he likewise calcined for four hours; the powder yielded most surprisingly to the magnet; so that it appears, that the opinion of Nennius, Boetius, and other ancient writers, was not absolutely destitute of foundation.

The white wood-stones are generally found in the ground at 2, 4, 6, and 8 miles distance from the lake, and sometimes very deep in the earth. The black ones are always found in the water, or on the shores of the lough; sometimes at the mouths of rivers or rivulets that empty themselves into it; but those with wood continuous have not yet been found above twenty yards distance from the water of the lake; that is, where the water reaches in the winter, or at other times.

Some of these stones are outwardly covered with a thin white substance, which has run through the pores of that part of the stone that was exposed to the air, and not covered by the water, mud, or clay; and on some others it is rather an incrustation of that white substance, which he takes to be the slimy, unctuous, saline parts of the petrescent juices that filled the outward pores of the stone, or coagulated on it. This white part scraped, and put into a crucible in a violent fire, could not be reduced to lime, though it grew red as coal. This powder calcined appeared through the microscope

quadrangular, like grains of salt; which made him suspect, that these petrifications contain, besides metalline, a great deal of saline particles, whose sides being strongly attracted to each other, and closely joined, hinders the fire from expanding the pores of these stones, and their being reduced to lime. This black stone, when broken, appears through the microscope very beautiful, and like cloth of silver, the pores and vessels of the wood being filled with white minute crystals.

Of these stones Mr. S. had some with wood outwardly continuous; others with wood inwardly; one, the least, part is of stone, the rest wood; another vice versa; another entirely wood, except a thin coat of stone on one side, which appears to be the very bark; one stone which at one end distinctly shows the annual ringlets of the wood; one that shows the wood, before it was petrified, had been bent, and partly broken, the fissure being filled with a sparry matter, and appears plainly from the present appearance and position of the fibres of the stone. Some of these stones strike fire with a steel, and others by a strong collision, emit a train of sparks. Some of these stones show the grain of holly, ash, and fir. He had only one piece of oak petrified, easily distinguished by its grain; it shows the very knots of the wood where young twigs were cut; and has a hole made through it before it was petrified.

As for these stones being fit for sharpening or setting of razors, &c. the black ones are rather too hard, and the white ones too soft. The whetstones or hones, vulgarly so called, which are sold for Lough-Neagh stones, are none of these, but of a soft gritty kind, and found near Drogheda.

When these stones with wood continuous are taken out of the water, mud, or clay, the woody part dries, cracks, and falls away; which is the reason why few can be well preserved; and besides, every body, unwilling to trust their eyes, will touch and scrape the wood, aud thus destroy the most curious part of the stone.

[*Phil. Trans. Abr.* 1746.]

We have copied the preceding paper, not more for the curious and unquestionable fact it contains, than to exhibit a proof of the infant state of mineralogy not longer ago than the middle of the last century. The above paper is succeeded in the same excellent journal by another on the same subject, furnished by the justly ce-

Engraved by Angus from a Drawing | *for the Gallery of Nature & Art.*

VIEW OF THE PETRIFYING SPRING, OR DROPPING WELL.

AT KNARESBOROUGH IN YORKSHIRE.

London. Published by [illegible] Chancery Lane [illegible]

lebrated Dr. George Berkeley, Lord Bishop of Cloyne, who in the course of his theory to account for the petrifying property of the lake, gives us his opinion that stones are unorganized vegetables, formed by an accretion of salts; which he urges in opposition to those of his own age, who conceived stones to be organized vegetables produced from seeds. Waters impregnated with calcareous earth, and other petrifying materials, and productive of all the effects here spoken of with astonishment, are now known to be frequent in most parts of the world: one of the most curious examples, in point of picturesque scenery, is perhaps the Dropping-well at Knaresborough; and we have already noticed a similar property in several other waters, especially in the lake of Solfatara in Campagna.

[EDITOR.]

SECTION XI.

Inundations.

WE have already observed that many of the large rivers of the east, as the Nile, the Ganges, and the Indus, are subject to periodical exundations, and have pointed out some of the more obvious causes of such an effect. There are others, however, that are subject to occasional overflows, and in many instances from causes that are altogether concealed. Among these we may perhaps enumerate the inundation of the Thames, about the year 1705, at Dagenham and Havering marches in Essex, which made an excavation nearly twenty feet deep, and laid open a great number of trees, mostly alder, buried under a soil obviously composed of the mud of the Thames, and which had, in all probability, been overthrown by some previous inundation of a similar kind.

The following, in the island of Mauritius, is to the same effect: On the 22d of March, 1696, observes Mr. Witsen, at half an hour after twelve o'clock, being calm but a little rainy, the river which passes by the plain ground of Noardwyek, in the space of a quarter of an hour swelled to such a height, that the sugar-mill, the sugar-work, and almost all the said ground was ruined, the most part of the sugar-canes being rooted or torn out of the ground by the violence of the torrent. It cannot be imagined what had caused so sudden a swelling of this river, for the rain was not very hard, and could not have produced that effect; for about twelve o'clock, when the com-

pany's servants assembled for dinner, the water of the river was at its ordinary height, and before they had half dined all the country was flooded a foot higher than two years since, when there was a hurricane and a most violent storm. It is very remarkable, that at one o'clock all the extraordinary water was gone, and the river again at its ordinary height. There has been no earthquake that could cause it, neither was there any such thing in other rivers.

In other instances the cause is peculiarly clear, though the violence with which it operates, is most ruinous and astonishing. The following is a case of this kind that occurred in the valley of St. John's, near Keswick in Cumberland, August 22, 1749. We take the account as published in the Phil. Trans. for 1750, and communicated by John Lock, Esq. F.R.S.

This remarkable fall of water happened at nine o'clock in the evening, in the midst of the most terrible thunder, and incessant lightning, ever known in that part in the memory of the oldest man living, the preceding afternoon having been extremely hot and sultry. And what seems very uncommon, and difficult to account for, the inhabitants of the vale, of good credit, affirm they heard a strange buzzing noise like that of a malt-mill, or the sound of wind in the tops of trees for two hours together before the clouds broke. From the havock it has made in so short a time, for it was all over in less than two hours, it must have far exceeded any thunder-shower that we have ever seen. Most probably it was a spout or large body of water, which, by the rarefaction of the air, occasioned by that incessant lightning, broke all at once on the tops of these mountains, and so came down in a sheet of water on the valley below.

This little valley of St. John's lies east and west, extending about three miles in length and half a mile broad, closed in on the south and north sides, with prodigious high, steep, rocky mountains: those on the north side, called Legburthet Fells, had almost the whole of this cataract. It appears also that this vast spout did not extend above a mile in length; for it had effect only on four small brooks, which came trickling down from the sides of the rocky mountains. But no person, that does not see it, can form any idea of the ruinous work occasioned by these rivulets at that time, and in the space of an hour and half. At the bottom of Catcheety

Gill, which is the name of the greatest, stood a mill and a kiln, which were entirely swept away, in five minutes time, and the place where they formerly stood, now covered with huge rocks, and rubbish, three or four yards deep. One of the mill-stones cannot be found, being covered, as is supposed, in the bottom of this heap of rubbish.

In the violence of the storm, the mountain has tumbled so fast down, as to choak up the old course of this brook; and it has forced its way through a shivery rock, where it now runs in a great chasm, four yards wide, and between eight and nine deep. In the course of each of these brooks, such monstrous stones, or rather rocks, and such vast quantities of gravel and sand, are thrown on their little meadow-fields, as render the same absolutely useless, aad never to be recovered.

It would surpass all credit to give the dimensions and weight of some rocks, which are not only tumbled down the steep parts of the mountains, but carried a considerable way into the fields, several thrown on the banks larger than a team of 10 horses could move. Near a place called Lobwath, one was carried a great way, which was 676 inches, or near 19 yards about. The damage done to the grounds, houses, walls, fences, highways, with a loss of the corn and hay then on the ground, is computed variously, by some at 1000l. by others at 1500l.

One of these brooks, which is called Mose or Mosedale Beck, which rises near the source of the others, but runs north from the other side of Legburthet Fells, continues still to be foul and muddy, having, as is supposed, worn its channel so deep in some part of its course, as to work on some mineral substance, which gives it the colour of water flowing from lead mines, and is so strong as to tinge the river Derwent, into which it empties itself, even at the sea, near 20 miles from their meeting.

No country is more unfortunately exposed to ruinous inundations than Holland, in consequence of the flatness of the country: the barriers formed by its dykes or sea-banks against the incroachments of the tides, being occasionally, from the united action of rain, wind, and sea-storms, being completely swept away, and the whole country overflowed with the watery devastation. Such was particularly the case in the year 1430; and again in 1686, of

which last the following is the account contained in the *London Gazette*.

" Groningen, Nov. 26.—On Friday the 22d instant, it blew the whole day a most violent storm from the S. E.; towards night the wind changed to the W. then to the N. W. afterwards to the N. E. and back again to the N. W. The weather continued thus tempestuous all night, accompanied with thunder and lightning; the chimneys and roofs of a great many houses were blown down, and much more mischief was done, but it was not comparable to that which followed; for the dykes not being able to resist the violence of the sea, agitated by these terrible storms, the whole country between this and the Delfziel, being about eighteen English miles, was the next morning overwhelmed with water, which in many places were eight foot higher than the very dykes, and many people and thousands of cattle were drowned, the water breaking even through the walls of the town of Delfziel, to that height that the inhabitants were forced to betake themselves to their garrets and upper rooms for shelter. The whole village of Oterdam is in a manner swept away. At Termunderzyl, there is not one house left, above three hundred people being drowned there, and only nineteen escaping. Hereskes, Weywert, Woldendorp, and all the villages near the Eems, have suffered extremely. The Western quarter has likewise had its share in this calamity, and the highest lands have not escaped. On Sunday and yesterday it reached this city; the lower parts whereof are now all under water. From the walls of this city we can see nothing but the tops of houses and steeples that remain above water. In a word, the misery and desolation is greater than can be expressed.

" It's impossible to describe the present sad condition of this province, occasioned by a most terrible inundation that happened the 22d instant; the like has not been known these hundred years. The whole province, except the higher parts of this city, lies under water; whole villages have been swept away, and a great many people, with abundance of cattle, drowned; and those that have escaped, sheltering themselves in garrets and upper rooms, are in great distress for want of relief: nothing but lamentations, and the jangling of bells for help, is heard through the whole country; and though all possible care is taken to assist them from hence,

DREADFUL DISRUPTION OF THE DYKES IN HOLLAND, 1430.

and other places, yet there not being boats enought to afford help to all, its to be feared many will be lost for want of it. At Oterdam, near Delfziel, but twenty-five persons have escaped; in the village of Peterborne there are but three houses left standing, and in general, all the houses that stood near the dyke have been swept away."

Instances of this kind might be selected to infinity: but we shall confine ourselves to the following extraordinary agitation of the waters of Loch Tay, given in a letter from the Reverend Thomas Fleming to the Reverend John Playfair, M. A.*

"I did not return from the excursion on which I was when I had the pleasure to see you at Dundee till last Tuesday night. On my arrival, I found your letter respecting the phænomenon that lately happened in this neighbourhood. Although ill qualified to give you satisfaction upon this subject, I shall, however, comply with your desire, and give you the most accurate account of that phænomenon which I have been able to obtain.

On Sunday the 12th of September, 1784, about nine o'clock in the morning, an unusual agitation was observed in Loch Tay, near the village of Kenmore. That village stands at the east end of the lake, having the river, which there issues from the lake, on the north side, and a bay, about 160 yards in length and 200 yards in breadth, on the south. The greater part of this bay is very shallow, being generally no more than than two or three feet deep; but before it joins the body of the lake, it becomes suddenly very deep. At the extremity of this bay, the water was observed to retire about five yards within its ordinary boundary, and in four or five minutes to flow out again. In this manner, it ebbed and flowed successively three or four times during the space of a quarter of an hour, when, all at once, the water rushed from the east and west, in opposite currents, towards a line across the bay, and about the edge of the deep, rose in the form of a great wave, to the height of five feet above the ordinary level, leaving the bottom of the bay dry, to the distance of between 90 and 100 yards from its natural boundary. When the opposite currents met, they made a clashing noise, and foamed; and the stronger impulse being from the east, the wave,

* See Transactions of the Royal Society of Edinburgh, Vol I. p. 200.

after rising to its greatest height, rolled westward, but slowly, diminishing as it went, for the space of five minutes, when it wholly disappeared. As the wave subsided, the water flowed back with some force, and exceeded its original boundary four or five yards; then it ebbed again about ten yards, and again returned, and continued to ebb and flow in this manner for the space of two hours, the ebbings succeeding each other at the distance of about seven minutes, and gradually lessening till the water settled into its ordinary level.

At the same time that the undulation was observed in the bay on the south side of the village, the river on the north was seen to run back; the weeds at its bottom, which before pointed with the stream, received a contrary direction; and its channel was left dry above twelve feet from either edge. Under the bridge, (which is sixty or seventy yards from the lake), the current failed, and the bed of the river appeared where there had been eighteen inches of water.

During the whole time that this phænomenon was observed, the weather was calm. It could barely be perceived that the direction of the clouds was from N. E. The barometer (as far as I can recollect) stood the whole of that and the preceding day about 29½ inches.

On the next, and the four succeeding days, an ebbing and flowing was observed nearly about the same time, and for the same length of time, but not at all in the same degree as on the first day. A similar agitation was remarked at intervals, some days in the morning, other days in the afternoon, till the 15th of October, since which time no such thing has been observed.

I have not heard (although I have made particular enquiry) that any motion of the earth was felt in this neighbourhood, or that the agitation of the water was observed any where but about the village of Kenmore.

The village of Kenmore is situated nearly in the parallel of 56° 35′, and about 1° west of the meridian of Edinburgh. Loch Tay extends from hence somewhat more than 15 miles W. S. W. Its medium breadth is not much less than a mile, and its depth must be very considerable, if one may judge from the height of the adjacent mountains.

EDITOR.

CHAP. XXXII.

THE OCEAN, ITS PROPERTIES AND DIVISIONS.

SECTION I.

1. *Introductory Remarks.*

During the progress of the earth, under the control of the Almighty fiat, from a state of chaos to a state of order, the laws of gravity seem uniformly to have maintained their power. And hence the immense mass of water which at first lay heterogeneously intermixed with the other principles of things, was gradually pressed out from the rest, ascended to the surface, as the lightest material of the whole, united its particles into one common body, and at length entered in an aggregate form into those immense hollows which were best fitted for its reception. It is these hollows which constitute the bed of the ocean. Hence the natural division of the surface of the globe is into sea and land; about three-fourths of the whole being occupied by water, though probably no where to a depth comparatively very considerable; at most not more than that of a few miles on an average. The larger portions of the land we denominate continents; and, in like manner we call the larger divisions of the ocean seas; the distinctive character of the water as compared with that of lakes and rivers, being its saltness, from its holding in solution a considerable quantity of muriat of soda, the source of which we shall presently enquire into. The larger seas are themselves, however, not unfrequently dignified, but improperly, with the name of oceans. Thus that vast expanse of water which lies to the westward of the northern and southern continents of America, is, on account of the uniform and temperate gales which sweep its surface within the tropics, denominated "the Pacific Ocean;" which has again been distinguished into the Northern and Southern Pacific, the equator being considered as the boundary of each, and "the Southern Ocean," being consequently that part of the general assemblage of waters which rolls in the direction from about the fortieth degree of latitude to-

ward the south pole. So likewise we speak of the Indian Ocean as extending from the eastern shores of Africa along the southern coasts of Asia; and the Atlantic Ocean as dividing Europe and Africa from the two American continents, while the waters which occupy the polar regions are called the *Northern Sea.*

Among the chief of those less expansive sheets of water, or those properly called seas, we may mention the Baltic, the Mediterranean Sea, the Black and the Red Seas: the Caspian Sea, being entirely encompassed by land, might properly be styled a lake, but as its water possesses the quality of saltness, it is ranked among the seas; yet Lake Superior, in North America, is supposed to be of greater circumference than the Caspian Sea; the one being at least fourteen hundred miles around its shores, and the other not more than twelve hundred.

Of the origin of this division into different seas, and seas of different depths, we cannot speak with certainty. It is highly probable that many of the larger excavations and partitions which we meet with now, have existed, without much change in regard to their extent, from the creation: others have undoubtedly been the result of that conflict which is perpetually taking place between the elements of land and water, and which has given rise for the most part to islands, isthmuses and peninsulas: while subterraneous volcanos, and the indefatigable exertions of corals, madrepores, tubifores, and other restless and multitudinous zoophytes, have laid, and are daily laying a foundation for new islands or continents in the middle of the widest and deepest seas; all which will furnish us with an additional source of enquiry, and is indeed well worthy of examination.

There is another peculiar feature which characterises the waters of the ocean, and which ought by no means to be overlooked on the present occasion, and that is its tides and currents, and the causes which have been assigned for them; which will necessarily lead us into an examination of the temperature of the ocean at different depths, the influence of the heavenly bodies, and especially of the moon upon its general mass.

The sections that follow under this chapter will be found directed to these subjects, and will close that important and extensive divisions of NATURAL HISTORY, which embraces the superficial phænomena to which we have given the name of the globe.

DITOR.

SECTION II.

Alternate Advances and Recessions of the Sea.

FROM what has been already observed of the earth and the ocean, there can be no doubt that they are both in a state of continual fluctuation. The earth, the common magazine for men, animals and vegetables, is continually furnishing its stores to their support. But the matter which is thus derived from it, is soon restored and laid down again, to be prepared for fresh mutations. The transmigration of souls is no doubt false and whimsical; but nothing can be more certain than the transmigration of bodies: the spoils of the meanest reptile may go to the formation of a prince; and, on the contrary, as the poet has it, the body of Cæsar may be employed in stopping a beer-barrel. From this, and other causes, therefore, the earth is in continual change. Its internal fires, the deviation of its rivers, and the falling of its mountains, are daily altering its surface; and geography can no longer recollect the lakes and the vallies that history once fondly dwelt upon.

But these changes are nothing to the instability of the ocean. It would seem that inquietude was as natural to it as fluidity. It is first seen with a constant and equable motion going towards the west; the tides then interrupt this progression, and for a time drive the waters in a contrary direction; besides these agitations, the currents act their part in a smaller sphere, being generally greatest where the other motions of the sea are least, namely, nearest the shore: the winds also contribute their share in this universal fluctuation; so that scarcely any part of the sea is wholly seen to stagnate.

Nil enim quiescit, undis impellitur unda,
Et spiritus et calor toto se corpore miscent *.

As this great element is thus changed, and continually labouring internally, it may be readily supposed that it produces correspondent changes upon its shores, and those parts of the earth subject to its influence. In fact, it is every day making considerable alterations, either by overflowing its shores in one place, or deserting them in others; by covering over whole tracts of country, that were culti-

* Nothing is still; o'er surges surges pass;
And heat and action mix, through all the mass.

vated and peopled, at one time; or by leaving its bed to be appropriated to the purposes of vegetation, and to supply a new theatre for human industry at another.

In this struggle between the earth and the sea for dominion, the greatest number of our shores seem to defy the whole rage of the waves, both by their height and the rocky materials of which they are composed. The coasts of Italy, for instance, are bordered with rocks of marble of different kinds, the quarries of which may easily be distinguished at a distance from sea, and appear like perpendicular columns, of the most beautiful kinds of marble, ranged along the shore. In general, the coasts of France, from Brest to Bourdeaux, are composed of rocks; as are also those of Spain and England, which defend the land, and only are interrupted, here and there, to give an egress to rivers, and to allow the conveniences of bays and harbours to our shipping. It may be in general remarked, that wherever the sea is most violent and furious, there the boldest shores, and of the most compact materials, are found to oppose it. There are many shores several hundred feet perpendicular, against which the sea, when swollen with tides or storms, rises and beats with inconceivable fury. In the Orkneys, where the shores are thus formed, it sometimes, when agitated by a storm, rises two hundred feet perpendicular, and dashes up its spray, together with sand, and other substances that compose its bottom, upon land, like showers of rain.

Hence, therefore, we may conceive how the violence of the sea, and the boldness of the shore, may be said to have made each other. Where the sea meets no obstacles, it spreads its waters with a gentle intumescence, till all its power is destroyed, by wanting depth to aid the motion. But when its progress is checked in the midst, by the prominence of rocks, or the abrupt elevation of the land, it dashes with all the force of its depth against the obstacle, and forms by its repeated violence, that abruptness of the shore which confines its impetuosity. Where the sea is extremely deep, or very much vexed by tempests, it is no small obstacle that can confine its rage—and for this reason we see the boldest shores projected against the deepest waters; all less impediments having long before been surmounted and washed away.

In places where the force of the sea is less violent, or its tides less rapid, the shores are generally seen to descend with a more gradual

declivity Over these, the waters of the tide steal by almost imperceptible degrees, covering them for a large extent, and leaving them bare on its recess. Upon these shores the sea seldom beats with any great violence, as a large wave has not depth sufficient to float it onwards; so that here only are to be seen gentle surges making calmly towards land, and lessening as they approach. As the sea, in the former description, is generally seen to present prospects of tumult and uproar, here it more usually exhibits a scene of repose and tranquil beauty. Its waters, which when surveyed from the precipice afforded a muddy greenish hue, arising from their depth and position to the eye, when regarded from a shelving shore wear the colour of the sky, and seem rising to meet it. The deafening noise of the deep sea, is here converted into gentle murmurs; instead of the water's dashing against the face of the rock, it advances and recedes, still going forward, but with just force enough to push its weeds and shells, by insensible approaches, to the shore.

There are other shores, beside those already described, which either have been raised by art to oppose the sea's approaches, or from the sea's gaining ground, are threatened with imminent destruction. The sea being thus seen to give and take away lands at pleasure, is, without question, one of the most extraordinary considerations in all natural history. In some places it is seen to obtain the superiority by slow and certain approaches; or to burst in at once, and overwhelm all things in undistinguished destruction; in other places it departs from its shores, and where its waters have been known to rage it leaves fields covered with the most beautiful verdure.

The formation of new lands, by the sea's continually bringing its sediment to one place, and by the accumulation of its sands in another, is easily conceived. We have had many instances of this in England. The island of Oxney, which is adjacent to Romney-marsh, was produced in this manner. This had for a long time been a low level, continually in danger of being overflown by the river Rother; but the sea, by its depositions, has gradually raised the bottom of the river, while it has hollowed the mouth; so that the one is sufficiently secured from inundations, and the other is deep enough to admit ships of considerable burthen. The like also may be seen at that bank called the Dogger-sands, where two tides

meet, and which thus receive new increase every day, so that in time the place seems to promise fair for being habitable earth. On many parts of the coasts of France, England, Holland, Germany, and Prussia, the sea has been sensibly known to retire.

In Italy there is a considerable piece of ground gained at the mouth of the river Arno; and Ravenna, that once stood by the sea-side, is now considerably removed from it. But we need scarce mention these, when we find that the whole republic of Holland seems to be a conquest upon the sea, and in a manner rescued from its bosom. The surface of the earth, in this country, is below the level of the bed of the sea. The province of Jucatan, a peninsula in the gulph of Mexico, was formerly a part of the sea: this tract, which stretches out into the ocean an hundred leagues, and which is above thirty broad, is every where, at a moderate depth below the surface, composed of shells, which evince that its land once formed the bed of the sea. In France, the town of Aigues Mortes was a port in the times of St. Louis, which is now removed more than four miles from the sea. Psalmodi, in the same kingdom, was an island in the year 815, but is now more than six miles from the shore. All along the coasts of Norfolk, there is good reason for belief, that in the memory of man the sea has gained fifty yards in some places, and has lost as much in others.

Thus numerous, therefore, are the instances of new lands having been produced from the sea, which, as we see, is brought about two different ways: first, by the waters raising banks of sand and mud where their sediment is deposited; and secondly, by their relinquishing the shore entirely, and leaving it unoccupied to the industry of man.

But as the sea has been thus known to recede from some lands, so has it, by fatal experience, been found to incroach upon others: and, probably, these depredations on one part of the shore, may account for their dereliction from another; for the current which rested upon some certain bank, having got an egress in some other place, no longer presses upon its former bed, but pours all its stream into the new entrance, so that every inundation of the sea may be attended with some correspondent dereliction of another shore.

However this may be, we have numerous histories of the sea's inundations, and its burying whole provinces in its bosom. Many

countries that have been thus destroyed, bear melancholy witnesses to the truth of history; and shew the tops of their houses, and the spires of their steeples, still standing at the bottom of the water. One of the most considerable inundations we meet with in history, is that which happened in the reign of Henry I. which overflowed the estates of the Earl Godwin, and forms now that bank called the Goodwin Sands. In the year 1546, a similar irruption of the sea destroyed an hundred thousand persons in the territory of Dort; and yet a greater number round Dollart. In Friezland and Zealand there were more than three hundred villages overwhelmed; and their remains continue still visible at the bottom of the water in a clear day. The Baltic sea has, by slow degrees, covered a large part of Pomerania; and, among others, destroyed and overwhelmed the famous port of Vineta. In the same manner, the Norwegian sea has formed several little islands from the main land, and still daily advances upon the continent. The German sea has advanced upon the shores of Holland, near Catt; so that the ruins of an ancient citadel of the Romans, which was formerly built upon this coast, are now actually under water. To these accidents several more might be added; our own historians and those of other countries abound with them; almost every flat shore of any extent being able to shew something that it has lost, or something that it has gained from the sea.

There are some shores on which the sea has made temporary depredations; where it has overflowed, and after remaining perhaps some ages, it has again retired of its own accord, or been driven back by the industry of man. There are many lands in Norway, Scotland, and the Maldives islands, that are at one time covered with water, and at another free. The country round the Isle of Ely, in the times of Bede, about a thousand years ago, was one of the most delightful spots in the whole kingdom. It was not only richly cultivated, and produced all the necessaries of life, but grapes also that afforded excellent wine. The accounts of that time are copious in the description of its verdure and fertility; its rich pastures, covered with flowers and herbage; its beautiful shades and wholesome air. But the sea breaking in upon the land, overwhelmed the whole country, took possession of the soil, and totally destroyed one of the most fertile vallies in the world. Its air, from being dry and healthful, from that time become most

unwholesome, and clogged with vapours; and the small part of the country that by being higher than the rest escaped the deluge, was soon rendered uninhabitable from its noxious vapours. Thus this country continued under water for some centuries; till, at last, the sea, by the same caprice which had prompted its invasions, began to abandon the earth in like manner. It has continued for some ages to relinquish its former conquests; and although the inhabitants can neither boast the longevity nor the luxuries of their former pre-occupants, yet they find ample means of subsistence; and if they happen to survive the first years of their residence there, they are often known to arrive to a good old age.

But although history be silent as to many other inundations of the like kind, where the sea has overflowed the country, and afterward retired, yet we have numberless testimonies of anothernature, that prove it beyond the possibility of doubt: as for example, those numerous trees that are found buried at considerable depths in places where either rivers or the sea has accidentally overflown. At the mouth of the river Ness, near Bruges, in Flanders, at the depth of fifty feet, are found great quantities of trees lying as close to each other as they do in a wood: the trunks, the branches, and the leaves, are in such perfect preservation, that the particular kind of each tree may instantly be known. And we have already adverted to similar facts in a preceding chapter. About five hundred years ago, this very ground was known to have been covered with the sea; nor is there any history or tradition of its having been dry ground, which we can have no doubt must have been the case. Thus we see a country flourishing in verdure, producing large forests, and trees of various kinds, overwhelmed by the sea. We see this element depositing its sediment to an height o fifty feet; and its waters must, therefore, have risen much higher. We see the same, after it has thus overwhelmed and sunk the land so deep beneath its slime, capriciously retiring from the same coasts, and leaving that habitable once more which it had formerly destroyed. All this is wonderful; and perhaps, instead of attempting to enquire after the cause, which has hitherto been inscrutable, it will best become us to rest satisfied with admiration.

At the city of Modena, in Italy, and about four miles round it, wherever the soil is dug into, when the workmen arrive at the depth of

sixty-three feet, they come to a bed of chalk, which they bore with an augre five feet deep: they then withdraw from the pit, before the augre is removed, and upon its extraction, the water bursts up through the aperture with great violence, and quickly fills this new-made well, which continues full, and is affected neither by rains nor droughts. But that which is most remarkable in this operation, is the different layers of materials found in the course of the descent. At the depth of fourteen feet are found the ruins of an ancient city, paved streets, houses, floors, and different pieces of Mosaic. Under this is found a solid earth, that would induce one to think had never been removed; however, under it is found a soft oozy earth, made up of vegetables; and at twenty-six feet depth, large trees entire, such as walnut-trees, with the walnuts still sticking on the stem, and their leaves and branches in exact preservation. At twenty-eight feet deep, a soft chalk is found, mixed with a vast quantity of shells; and this bed is eleven feet thick. Under this, vegetables are found again, with leaves, and branches of trees as before; and thus alternately chalk and vegetable earth to the depth of sixty-three feet. These are the layers wherever the workmen attempt to bore; while in many of them they also find pieces of charcoal, bones, and bits of iron. From this description, therefore, it appears, that this country has been alternately overflowed and deserted by the sea, one age after another: nor were these overflowings and retirings of trifling depth, or of short continuance. When the sea burst in, it must have been a long time in overwhelming the branches of the fallen forest with its sediments; and still longer in forming a regular bed of shells eleven feet over them. It must have, therefore, taken an age at least to make any one of these layers; and we may conclude, that it must have been many ages employed in the production of them all. The land, also, upon being deserted, must have had time to grow compact, to gather fresh fertility, and to be drained of its waters, before it could be disposed to vegetation, or before its trees could have shot forth again to maturity.

From hence we see what powerful effects the sea is capable of producing upon its shores, either by overflowing some or deserting others; by altering the direction of these, and rendering those craggy and precipitate, which before were shelving. But the influence it has upon these is nothing to that which it has upon tha

great body of earth which forms its bottom. It is at the bottom of the sea that the greatest wonders are performed, and the most rapid changes are produced; it is there that the motion of the tides and the currents have their full force, and agitate the substances of which their bed is composed. But all these are almost wholly hid from human curiosity; the miracles of the deep are performed in secret; and we have but little information from its abysses, except what we receive by inspection at very shallow depths, or by the plummet, or from divers, who are known to descend from twenty to thirty fathoms.

[*Phil. Trans. Buffon. Abbé Fortis. Newton. Goldsmith. Payne.*]

SECTION III.

Formation of Coral Islands.

Few things are more curious or difficult to explain than the prodigious quantity of coral formed in the sea, especially in the tropical regions. Coral is the produce of different species of vermes, or worm tribes, and it consists chiefly of carbonate of lime. Now it is difficult to conceive where these animals procure such prodigious quantities of this substance. Sea-water, indeed, contains traces of sulphat of lime, but no other calcareous salt, as far as we know. Hence it would appear, that these creatures must either decompose sulphate of lime, though the quantity of that salt contained in sea-water seems inadequate to supply their wants, or, they must form carbonate of lime from the constituents of sea-water, in a way totally above our comprehension. Be that as it may, there is one consequence of this copious formation of coral in the tropical regions of considerable importance to navigation, which has been clearly pointed out by Mr. Dalrymple, and is now pretty well understood.

There is not a part of natural history, remarks this accurate observer, more curious, or perhaps to a navigator more useful, than an enquiry into the formation of islands. The origin of islands in general, is not the point to be discussed, but of low, flat, islands in the wide ocean, such as are most of those hitherto discovered in the vast South-sea. These islands are ge-

nerally long and narrow, they are formed by a narrow bar of [illegible]nd, inc[illegible]ing the sea within it; generally, perhaps always, with [illegible]me [illegible]nel of ingress at least to the tide, commonly with an [illegible]ng capable of receiving a canoe, and frequently sufficient to admit even larger vessels.

The origin of these islands will explain their nature. What led Mr. Dalrymple first to this deduction, was an observation of Abdul Roobin, a Sooloo pilot; that all the islands, lying off the N. E. coast of Borneo, had shoals to the eastward of them. These islands being covered to the westward by Borneo, the winds from that quarter do not attack them with violence. But the N. E. winds, tumbling in the billows from a wide ocean, heap up the coral with which those seas are filled. This, obvious after storms, is perhaps at all other times imperceptibly effected. The coral banks, raised in the same manner, become dry. These banks are found at all depths at all distances from shore, entirely unconnected with the land, and detached from each other: though it often happens that they are divided by a narrow gut, without bottom.

Coral banks also grow, by a quick progression, towards the surface; but the winds, heaping up the coral from deeper water, chiefly accelerate the formation of these into shoals and islands. They become gradually shallower, and when once the sea meets with resistance, the coral is quickly thrown up by the force of the waves breaking against the bank; and hence it is that, in the open sea there is scarcely an instance of a coral bank having so little water that a large ship cannot pass over, but it is also so shallow that a boat would ground on it. Mr. D. has seen these coral banks in all the stages; some in deep water, others with a few rocks appearing above the surface, some just formed into islands, without the least appearance of vegetation, and others, from such as have a few weeds on the highest part to those which are covered with large timber, with a bottomless sea at a pistol-shot distance.

The loose coral, rolled inward by the billows in large pieces, will ground, and the reflux being unable to carry them away, they become a bar to coagulate the sand, always found intermixed with coral; which sand, being easiest raised, will be lodged at top. When the sand bank is raised by violent storms, beyond the reach of common waves, it becomes a resting place to vagrant birds, whom the search of prey draws thither. The dung, feathers, &c.

increase the soil, and prepare it for the reception of accidental roots, branches, and seed, cast up by the waves, or brought thither by birds. Thus islands are formed: the leaves and rotten branches, intermixing with the sand, form in time a light black mould, of which in general these islands consist, more sandy as less woody; and when full of large trees, with a greater proportion of mould. Cocoa nuts, continuing long in the sea without losing their vegetative powers, are commonly to be found in such islands; particularly as they are adapted to all soils, whether sandy, rich, or rocky.

The violence of the waves, within the tropics, must generally be directed to two points, according to the monsoons. Hence the islands formed from coral banks, must be long and narrow, and lie nearly in a meridional direction. For even supposing the banks to be round, as they seldom are when large, the sea, meeting most resistance in the middle, must heave up the matter in greater quantities there than towards the extremities: and, by the same rule, the ends will generally be open, or at least lowest. They will also commonly have soundings there, as the remains of the banks, not accumulated, will be under water. Where the coral banks are not exposed to the common monsoon, they will alter their direction; and be either round, or extend in the parallel, or be of irregular forms, according to accidental circumstances.

The interior parts of these islands, being sea, sometimes form harbours capable of receiving vessels of some burthen, and Mr. D. believes always abound greatly with fish; and such as he has seen, with turtle-grass and other sea-plants, particularly one species, called by the Sooloos gammye, which grows in little globules, and is somewhat pungent as well as acid to the taste. It need not be repeated that the ends of those islands, only, are the places to expect soundings: and they commonly have a shallow spit running out from each point. Abdul Roobin's observation points out another circumstance, which may be useful to navigators: by consideration of the winds to which any islands are most exposed, to form a probable conjecture which side has deepest water; and from a view which side has the shoals, an idea may be formed which winds rage with most violence.

[*Thomson. Phil. Trans. Abr. Vol. XII.*]

To the above we have only to add, that the common foundation of all those clusters of islands which modern navigators have discovered in the Pacific Ocean, and to which the name of Polynesia has been given, as well as of those which belong to Australasia or New South Wales, and perhaps of New South Wales itself, is evidently of coral structure, immense reefs of which shoot out in every direction. And it is a circumstance peculiarly singular, that notwithstanding this prodigious quantity of lime in the form of coral, not a single bed, and scarcely a particle of chalk, has hitherto been met with either in the islands or on the continent.

There are other islands which are occasionally raised by the violent agency of the subterraneous volcanos. These, however, are comparatively but few in number, and in mass of matter bear no proportion to those which we have reason to believe are perpetually forming by the silent but persevering efforts of the sea-worms we are now more immediately adverting to: and as we have already given instances of such occasional disruptions from the bowels of the earth we need not enlarge upon them in the present place.

[*Editor.*]

SECTION IV.

Supposed Isthmus between Calais and Dover; occasional Attempts to unite Sea with Sea; and the Conjecture of a North-West Passage.

GEOGRAPHY has had its fancies as well as every other science, and among the more prominent of these may be reckoned the hypothesis and hypothetical attempts which we have enumerated at the head of this Section.

It was once a favourite opinion, that Great Britain and France had many years ago been united by an isthmus, or narrow neck of land, stretching across what is now the passage between Dover and Calais; and that this isthmus had been broken down and carried away by some violent force of the circumambient sea, before the commencement of any historical records. In the Philosophical Transactions, we have three or four papers upon this visionary subject. Two of them were written by Dr. Wallis, within two years of

his death, when he had reached his eighty-fifth year; and which affords a surprising proof of the activity of mind, and the perfect command of his faculties which that extraordinary man retained at so advanced an age *. The third paper, on the same subject, was written by Dr. William Musgrave †. This opinion was first broached by Camden, supported by Sumner, and opposed by Vossius. Dr. Wallis supports it with much learning, and points out the effects of the rupture with much ingenuity. He conceives, that the tradition mentioned by Plato, of the destruction of an island in the Atlantic Ocean, related to the rupture of this isthmus; and Dr. Musgrave quotes the well-known passage in Virgil:

——Penitus toto *divisos* orbe Britannos;

as a proof that Virgil was aware of such a rupture, and alluded to it. When men have recourse to such proofs as these in support of an opinion, it affords clear evidence that they have nothing better to produce.

Another ingenious fancy that has occasionally been indulged, and in a few instances been attempted to be embodied into a living fact, is that of uniting one sea with another by a bold and magnificent canal cut through the isthmus by which they are occasionally separated. One of the earliest attempts of this kind of which we have any account, is the splendid undertaking to unite the Mediterranean with the Red Sea by means of the Pelusian branch of the Nile. This great work was begun by Sesostris, King of Egypt, and carried on by his successors down to the time of Ptolemy Philadelphus. It was denominated the canal of the kings; was a hundred cubits broad, and of a sufficient depth to bear the largest vessels. It was nearly but never completely finished; the great objection being drawn from an unfounded idea that the bed of the Red Sea is much loftier than the soil of Egypt, and consequently that if the canal were to be opened, it would drown the country, or at least destroy all the benefit of the periodical exundation of the Nile. Trajan, however, appears to have made some attempt to revive this magnificent speculation; and M. Petit, and several other celebrated French engineers, were consulted by their own government as to the expe-

* Phil. Trans. 1701. Vol. xxii. p. 967 and 1030.

† Phil. Trans. 1717. Vol. xxx. p. 589.

diency of its execution about the middle of the seventeenth century.

An equally splendid, but equally unsuccessful attempt was commenced by Charlemagne in the year 793 for uniting the Euxine and the Ocean by a channel, which was designed to be 2000 paces long and 100 broad, and to run from the river Altmull falling into the Danube above Ratisbon, to the river Noth passing by Nuremberg, and thence into the Rhine by the Maine. The attempt proved abortive, though begun under considerable auspices of success.

One of the most favourite hypotheses that has been indulged by geographers and circumnavigators of different ages, is that of a passage to India from North America in a westward direction: and upon this subject we cannot do better than quote the following paper upon the subject as printed in the Philosophical Transactions for 1675, in which the reader will observe that the most sanguine expectations were indulged at that period.

It is sufficiently known to those who have made any inspection into the navigation of this and the former age, how solicitously the States of the United Provinces have laboured to encourage those, who should first discover a more compendious and shorter passage by the north, to China, Japan, and other eastern countries. But those who first ventured on this enterprise, found by sad experience, that the success did not answer their expectation and hopes.

Those who immediately succeeded them in that adventure, were not much more successful; for treading the same steps that the former had done, they were involved in the same difficulties; being misled by an opinion, that that part of the sea, which lies between Nova-zembla and the continent of Tartary, was passable, and that they might sail through that to China. But it is now well known to the Muscovites and others, that Nova-zembla is no island, but a part of Tartary; to which it is annexed on the east by a large neck of land, that the arm of sea, into which there is a passage through the Weigath-straits, is not really sea, but a lake of fresh water; the great abundance of rivers, which out of Asia empted themselves into this gulf, causing this freshness; so that it is not to be counted strange, if, especially in the winter season, these waters are strongly frozen.

Nor is it to be wondered at, that the navigation of William Barentz, otherwise an experienced mariner, was unsuccessful who passed along the coast of Nova-zembla, as far as the 77th deg. of N. latitude, for it is well known, that most of those northern coasts are frozen up many leagues; though in the open sea it is not so; no nor under the pole itself, unless by accident, as when on the approach of summer, the frost breaks, and the ice which was near 40 or 50 leagues off the shore, breaks off from the land and floats up and down in the sea. These prodigious floats of ice were the chief obstruction to those that directed their course somewhat more to the north.

Some thirty years ago, certain merchants of Amsterdam attempted those seas with much better success than the former. Having advanced to the 79th or 80th deg. of northern latitude, they passed above a hundred leagues to the east of Nova-zembla. These being returned to their own country, with great hopes of finding encouragement to make further discoveries, petitioned the States General that they would be pleased to grant the navigation of the northern seas, and of the eastern, not yet discovered to them.—But the governors of the East India Company, being sensible how nearly this concerned them, presented a counter petition, desiring that the petition of the said merchants might for the future be referred to them and their consideration. The merchants finding their petitions thus crossed, they addressed themselves to the King of Denmark, who immediately granted their demands. Under his protection therefore they equipped two or three ships, such as they judged most proper for this voyage. On which the governor of the Dutch East India Company raised a considerable sum of money, and easily persuaded the mariners to desist from so dangerous a voyage, as they represented it; and that the merchants might have no just cause to complain of the said company, the mariners went to sea; but neglecting the directions and orders of those merchants, they steered their course directly for Spitzberg, took in their lading of fish, and returned home.

Upon which the East India Company omitted nothing to find out a passage through the north-eastern sea, for those who were to return into Europe from the East Indies. There was then much discourse of the Gulf of Ann, by which a passage was said to be

ope into t artarian Sea: and they had some hints from the peop of Japan and the Portuguese, about the country of Jezzo, which ay above Japan. But not resting satisfied with the bare relation, in the years 1652 and 1653, they sent out some skilful persons to discover those coasts; who passing beyond Japan, the 50th degree of N. latitude, arrived on the coast of Jezzo, where they fell into a narrow sea, yet broad and convenient enough to lead into the Northern Ocean. The opposite shores they called *het Compagnie land*, and an island seated in the middle of the gulf they called *het Staten Eyland.* Whether this land of Jezzo be annexed to Japan or not, the inhabitants of both countries doubt; because vast and inaccessible mountains interpose, which hinder the communication. Neither does it as yet clearly appear, whether this land of Jezzo be a part of Tartary, or whether by an arm of the sea divided from it. The Chinese affirm, that Tartary runs 300 China leagues eastward beyond their famous wall: so that if we follow these, the country of Jezzo and Japan may seem to be annexed to Tartary; but those of Jezzo say, that there runs an arm of the sea between them and Tartary: which opinion may seem to receive some confirmation from what those Hollanders affirm, who were shipwrecked some years since on Corea, a peninsula of China, where they saw a whale, upon whose back stuck a harping-iron of Gascony. It is therefore most probable, that this whale passed from Spitzbergen through the nearest arm of the sea, rather than through the more remote. After the experiments made by the governors of the East India Company, in the year 1652 and 1653, they resolved to proceed no further on the discovery; as well because the Emperor of Japan interdicted the navigation of foreigners into Jezzo, in regard, as they say, of the vast tribute which he annually raises from the silver mines there; as because they thought it may little conduce to their advantage, to have this compendious way of navigation discovered. And therefore they have thought fit to prohibit all further search into the navigation to Jezzo, and the adjacent countries; for which very reason they have also endeavoured to conceal their Austral plantations.

Now concerning that tract or space which lies between Spitzbergen, Nova-zembla, and the Straits of Jezzo, we have no reason to entertain any doubt; especially as many of the Muscovite

itineraries assure us, that the coast of Tartary runs [illegible] northward from Nova-zembla, but turns very much towards the east; so that the head land of Nova-zembla is far the most northern part of all Tartary.

It remains now to inquire by whar course, and in what season of the year, this voyage is best to be undertaken? It is hardly to be doubted, but that the strait which lies between Spitzberg and Nova-zembla may be passed; and the course to be directed to 78, 79, or 80 degrees of north latitude. If any shall proceed farther in the same work, he will find the passage shorter; for drawing a line from our seas through the 78th or 79th degree of latitude, to the Strait of Jezzo, it will be very near a straight line: but if any would, from the same degree of latitude, having passed Nova-zembla, choose to steer toward the coast of Tartary, and coast along by it, till he meet with some strait, he would find his course somewhat longer, but perhaps safer and better.

As to the time of the year, wherein this navigation ought to begin; it may be in the beginning of the spring, viz. in the month of March, when it is confessed by most men, that the winds and seas are favourable to those that sail to Spitzberg, and the places near the pole; and that they may run all that course from these parts in twelve or thirteen days: but when they have passed so far, if any man would design to sail to the Straits of Jezzo, he must steer his course towards the south. But then those motions of the winds and seas, which were favourable to those who sailed northward, will be contrary to those who stand southward; and they may long enough expect northern gales, which seldom blow till towards the latter end of summer, viz. in the month of August. If therefore any man would contrive to dispatch his voyage in the shortest time, it would be safest to make choice of that time of the year, where he might soonest make Spitzberg and return again, which might be in the beginning of summer: yet it would be safer to set out sooner, if the wind permit. And although this course should happily succeed, it follows not that I should advise them to observe the same in their return homeward; for things of that nature must be left to the prudence and conduct of discreet pilots and mariners, who ought to shun all near approach to the coasts and islands which they shall encounter, for fear of the ice; and that they always make choice of the most open seas, which are least

infected with it, and in which the colds are more moderate. For experience has sufficiently taught, that whole large seas are never known to be frozen, but only the sea coasts, from the plenty of fresh waters that run into the ocean, and the snows melted in it. And the same experience has taught, that there is not that danger from the floating ice, as is vulgarly apprehended, especially in seas not subject to violent storms, and in the 6th or rather the 8th month of the year.

When the nature of this sea, and of its several straits shall be more perfectly discovered, it is not to be doubted but that the whole voyage to Japan may be formed in five or six weeks at the most. But in case it should happen, that the ships should be forced to winter there, this might be done without much danger; provoided they avoided the unadvised example of the Dutch, who being necessitated to pass the winter in the most northern climates, planted themselves there upon the highest lands, in huts framed of thin boards; whereas they ought to sink their houses under ground, and to heap much earth over them; since it is scarcely possible for men to subsist in such an excessive severity of winter, unless they shelter themselves deep under the earth.—*Phil. Trans. Abr. Vol.* II. 1677.

We have only to add, that all hopes of a north-west passage have since been completely disappointed from the researches of modern navigators*. EDITOR.

SECTION V.

Saltness, and other Chemical Properties of the Ocean.

THE ocean is the great reservoir of water into which the lakes and rivers empty themselves, and from which is again drawn by evaporation that moisture which, falling in showers of rain, fertilizes the earth, and supplies the waste of the springs and waters. This constant circulation would naturally dispose one to believe, *a priori*, that the waters of the ocean do not differ much from the waters of rivers and lakes: but nothing would be more erroneous than such a conclusion; for the sea water, as every one knows, differs materially from common water in its taste, specific gravity, and other properties. It contains a much greater proportion of

* See farther upon this subject, ch. xxxvii, sections iii, iv, v.

saline matter, particularly of common salt, which is usually extracted from it. Indeed, if the sea were not impregnated with these saline bodies, the putrefaction of the immense mass of animal and vegetable matter which it contains would in a short time prove fatal to the whole inhabitants of the earth.

The absolute quantity of sea water cannot be ascertained, as its mean depth is unknown. Mr. De la Place has demonstrated, that a depth of four leagues is necessary to reconcile the height to which the tides are known to rise in the main ocean with the Newtonian theory of the tides *. If we suppose this to be the mean depth, the quantity of water in the ocean must be immense. Even on the supposition that its mean depth is not greater than the fourth part of a mile, its solid contents (allowing its surface to be three-fourths of that of the superficies of the earth) would be 32,058,939$\frac{3}{4}$ cubic miles.

Sea water has a very disagreeable bitter taste, at least when taken from the surface or near the shore; but when brought up from great depths, its taste is only saline †. Hence we learn that this bitterness is owing to the animal and vegetable substances with which it is mixed near the surface. Its specific gravity varies from 1·0269 to 1·0285 ‡. It does not freeze till cooled down to 25·2° § of Fahrenheit's scale.

It has been ascertained by the experiments of different chemists ||, and especially by those of Bergman, that sea water holds in solution muriate of soda, muriate of magnesia, sulphate of magnesia, and sulphate of lime; besides the animal and vegetable bodies with which it is occasionally contaminated. The average quantity of saline ingredients is 1-28th. Bergman found water taken up from the depth of 60 fathoms, near the Canaries, by Dr. Sparrman, to contain 1-24th. Lord Mulgrave found the water at the back of Yarmouth sands to contain about 1-32th part. Bergman found water taken up from a depth of sixty fathoms to contain only the following salts in the following proportions.

* *Mem. Par.* 1776, p. 213.

† Bergman, i. 180.

‡ Bladh. Kirwan's *Geological Essays*, p. 355.

§ Nairne, *Phil. Trans.* 1776, Part First.

|| Monnet, Lavoisier, Baumé, &c. have published analyses of sea water.

30·911 common salt.
6·222 muriate of magnesia.
1·000 sulphate of lime.

Mr. Lavoisier found 10,000 parts of sea water taken up on the west of Dieppe to contain the following salts :

1375 muriate of soda.
256 muriate of lime and magnesia.
156 muriate of magnesia.
87 lime.
84 salphate of soda and magnesia.

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or almost 1-5th of saline contents*; but this proportion is undoubtedly excessive. My analysis gives 1-30th of saline contents in the water of the Frith of Forth. The salts which I found were the same as those announced by Bergman, sulphate of magnesia excepted, which exists in all the specimens of sea water that I have examined; and the proportion of it is considerable.

As far as experiment has gone, the proportion of saline contents does not differ much, whatever be the latitude in which the water of the ocean is examined. Lord Mulgrave, in north latitude 86°, and 60 fathoms under ice, found the saline contents of sea water 0·0354; in latitude 74°, he found them 0·036; in latitude 60°, 0·034. Pages found sea water taken up in north latitude 45° and 39° to contain 0·04 of saline contents; and Baumé obtained by analysis, from water taken up by Pages in north latitude 34° and 14°, exactly the same proportions of saline matter. In southern latitudes Pages found the following proportions of saline matters :

Latitude.	Saline Matter.
49° 50′	0·0416
46 0	0·045
40 30	0·04
25 54	0·04
20 0	0·039
1 16	0·035

From the experiments made by Bladh on the specific gravity of sea water in different latitudes, it appears that the water contains more salt at the tropics than towards the equator.

* *Mem. Par.* 1772, as quoted by Kirwan.

If we were acquainted with the proportion between the saline contents of sea water and its specific gravity, it would be easy in all cases to ascertain the quantity of saline matter merely by taking the specific gravity of the water we wish to examine. This would require a set of experiments on purpose; dissolving in pure water different quantities of the salts contained in sea water in the proportions which they bear to each other, and ascertaining the specific gravity of every such solution. Dr. Watson has given us a Table for ascertaining that point, as far as common salt is concerned; and as the salt which he used was not perfectly pure, but contained a mixture of the different salts usually found in the sea, we may consider it as very nearly determining the proportion of saline contents in sea water as far as it goes. This Table therefore I shall here insert *.

Proportion of Salt.	Specific Gravity.	Proportion of Salt.	Specific Gravity.	Proportion of Salt.	Specific Gravity.
0	1·000	1-21st	1·032	1-84th	1·007
1-half	1·206	1-24th	1·029	1-108th	1·006
1-4th	1·160	1-27th	1·027	1-126th	1·005
1-5th	1·121	1-28th	1·025	1-144th	1·004
1-6th	1·107	1-30th	1·024	1-162nd	1·003
1-7th	1·096	1-32nd	1·023	1-192nd	1·0029
1-8th	1·087	1-36th	1·020	1-256th	1·0023
1-9th	1·074	1-39th	1·019	1-320th	1·0018
1-12th	1·059	1-42nd	1·015	1-448th	1·0017
1-14th	1·050	1-48th	1·014	1-512th	1·0014
1-15th	1·048	1-54th	1·013	1-848th	1·0008
1-16th	1·045	1-56th	1·012	1-1024th	1·0006
1-18th	1·040	1-72nd	1·009		

This Table was calculated at a temperature between 46° and 55°; but Mr. Kirwan has reduced part of it to the temperature of 62°, in order to compare it with the specific gravities of sea-water taken at that temperature, or at least reduced to it. The specific gravities, thus altered by Kirwan, are as follows:

Proportion of Salt.	Specific Gravity at 62°.
1-24th	1·0283
1-25th	1·0275
1-26th	1·0270
1-27th	1·0267
1-28th	1·0250

* Watson's *Chemical Essays*, p. 91.

1-30th	1·0233
1-39th	1·0185
1-44th	1·0133
1-56th	1·0105
1-108th	1·004
1-162nd	1·0023

This table will enable us to ascertain the saline contents of sea-water in different parts of the Atlantic and Indian Oceans, from the following Table of the specific gravity of sea-water in different parts of these oceans, constructed by Bladh, and reduced by Kirwan to the temperature of 62°*.

Latitude.	Longitude †.	Sp. Gr. at 62°.
North.	East.	
59° 39′	8° 48′	1·0272
57 18	18 48	1·0269
	West.	
57 01	1 22	1·0272
54 00	4 45	1·0271
44 32	2 04	1·0276
	East.	
44 07	1 00	1·0276
40 41	0 30	1·0276
34 40	1 18	1·0280
29 50	0 00	1·0281
	West.	
24 00	2 32	1·0284
18 28	3 24	1·0281
16 36	3 37	1·0277
14 56	3 46	1·0275
10 30	3 49	1·0272
5 50	3 28	1·0274
2 20	3 26	1·0271
1 25	3 30	1·0273
South.		
0 16	3 40	1·0277
5 10	6 00	1·0277
10 00	6 05	1·0285
14 40	7 00	1·0284
20 06	5 30	1·0285
25 45	2 22	1·0281
	East.	
30 25	7 12	1·0279
37 37	68 13	1·0276

* Kirwan's *Geol. Essays*, p. 350. † The Long. is counted from Teneriffe.

From this Table, compared with the last, we learn that the ocean contains most salt between south latitude 10° and 20°; the saline contents amounting to rather more than 1-24th. The quantity of salt between north latitude 18° and 34° is rather less than 1-24th: at the equator it is nearly 1-25th. The proportion of salt is least of all in north latitude 57°, where it amounts to little more than 1-27th.

From the experiments of Wilcke, we learn that the Baltic contains much less salt than the ocean; that the proportion of its salt is increased by a west wind, and still more by a north west wind. The specific gravity of the Baltic water, ascertained by this philosopher under these different circumstances, and reduced by Mr. Kirwan to the temperature of 62°, is exhibited in the following Table:

Specific Gravity.	
1·0030	Wind at E.
1.0067	Ditto at W.
1·0118	Storm at W.
1·0098	Wind at N.W.

From this Table it appears that the proportion of salt in the Baltic, when an east wind prevails, is only 1-108th; and that this proportion is doubled by a westerly storm: a proof not only that the saltness of the Baltic is derived from the neighbouring ocean, but that storms have a much greater effect upon the waters of the ocean than has been supposed *. The Euxine and Caspian Seas, if we believe Tournefort, are less salt than the ocean †; but it is probable that the Mediterranean is at least as salt as the Atlantic.

We have already observed, that the water of the Dead Sea differs exceedingly from sea-water, and have given the result of an analysis in proof of such observation. This water is in truth rather to be regarded as of the nature of a mineral water, and we have described it accordingly.

From the whole now offered it does not appear that the saline contents of the ocean differ very essentially in different parts of it, though the lakes and inland seas may evince some degree of disparity.

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* Kirwan's *Geoligical Essays*, p. 356.

† Tournefort's *Voyages*, ii, 410.

It was, however, an opinion of Dr. Halley, that however uniform the saltness of the ocean may be in different parts of it at a given period of time, its general mass has been progressively becoming more impregnated with saline materials, and hence actually salter to the taste, ever since the formation of the world; and he endeavours to ground a proof of the age of the world upon this circumstance. His paper, which is short and ingenious, is as follows.

"There have been many attempts made, and proposals offered, to ascertain from the appearances of nature, what may have been the antiquity of this globe of earth; on which, by the evidence of sacred writ, mankind has dwelt about 6000 years; or according to the Septuagint above 7000. But as we are there told that the formation of man was the last act of the Creator, it is no where revealed in Scripture how long the earth had existed before this last creation, nor how long those five days that preceded it may be to be accounted; since we are elsewhere told, that in respect of the Almighty a thousand years is as one day, being equally no part of eternity; nor can it well be conceived how those days should be to be understood of natural days, since they are mentioned as measures of time before the creation of the sun, which was not till the fourth day. And it is certain that Adam found the earth, at his first production, fully replenished with all sorts of other animals. This inquiry seeming to me well to deserve consideration, and worthy the thoughts of the Royal Society, I shall take leave to propose an expedient for determining the age of the world by a medium, as I take it, wholly new, and which, in my opinion, seems to promise success, though the event cannot be judged of till after a long period of time; submitting the same to their better judgment. What suggested this notion was an observation I had made, that all the lakes in the world, properly so called, are found to be salt, some more some less than the ocean, which in the present case may also be esteemed a lake; since by that term I mean such standing waters as perpetually receive rivers running into them, and have no exit or evacuation.

"The number of these lakes, in the known parts of the world, is exceedingly small, and indeed on inquiry I cannot be certain there are in all any more than four or five, viz. 1st. The Caspian Sea; 2dly, The Mare Mortuum, or Lacus Asphaltites; 3dly, The lake on which stands the city of Mexico; and 4thly, The lake of Titicaca in Peru, which by a channel of about fifty leagues communi-

cates with a fifth and smaller, called the lake of Paria, neither of which have any other exit. Of these, the Caspian, which is by much the greatest, is reported to be somewhat less salt than the ocean. The Lacus Asphaltites is so exceedingly salt, that its waters seem fully sated, or scarcely capable to dissolve any more; whence in summer-time its banks are incrustated with great quantities of dry salt, of somewhat a more pungent nature than the marine, as having a relish of sal ammoniac; as I was informed by a curious gentleman who was on the place.

"The lake of Mexico, properly speaking, is two lakes, divided by the causeways that lead to the city, which is built in islands in the midst of the lake, undoubtedly for its security; after the idea, probably, which its first founders borrowed from their beavers, who build their houses on dams they make in the rivers after that manner. Now that part of the lake which is to the northward of the town and causeways, receives a river of a considerable magnitude, which being somewhat higher than the other, does with a small fall exonerate itself in the southern part, which is lower. Of these the lower is found to be salt, but to what degree I cannot yet learn; though the upper be almost fresh.

"And the lake of Titicaca, being nearly eighty leagues in circumference, and receiving several considerable fresh rivers, has its waters, by the testimony of Herrera and Acosta, so brackish as not to be potable, though not fully so salt as that of the ocean; and the like they affirm of that of Paria, into which the lake of Titicaca does in part exonerate itself, and which I doubt not will be found much salter than it, if it were inquired into.

"Now I conceive that as all these lakes receive rivers, and have no exit or discharge, so it will be necessary that their waters rise and cover the land, until such time as their surfaces are sufficiently extended, so as to exhale in vapour that water which is poured in by the rivers; and consequently that lakes must be larger or smaller, according to the quantity of the fresh they receive. But the vapours thus exhaled are perfectly fresh; so that the saline particles brought in by the rivers remain behind, while the fresh evaporates; and hence it is evident that the salt in the lakes will be continually augmented, and the water grow salter and salter. But in lakes that have an exit, as the lake of Genesaret, otherwise called that of Tiberias, and the upper lake of Mexico, and indeed in most others,

the water being continually running off, is supplied by new fresh river water, in which the saline particles are so few as by no means to be perceived."

"Now if this be the true reason of the saltness of these lakes, it is not improbable but that the ocean itself is become salt from the same cause, and we are thereby furnished with an argument for estimating the duration of all things, from an observation of the increment of saltness in their waters. For if it be observed what quantity of salt is at present contained in a certain weight of the water, of the Caspian Sea, for example, taken at a certain place, in the driest weather; and after some centuries of years the same weight of water, taken in the same place, and under the same circumstances, be found to contain a sensibly greater quantity of salt than at the time of the first experiment, we may by the rule of proportion, make an estimate of the whole time wherein the water would acquire its present degree of saltness.

"And this argument would be the more conclusive, if by a like experiment a similar increase in the saltness of the ocean should be observed: for that, after the same manner as aforesaid, receives innumerable rivers, all which deposit their saline particles therein; and are again supplied, as I have elsewhere showed, by the vapours of the ocean, which rise from it in atoms of pure water, without the least admixture of salt. But the rivers in their long passage over the earth imbibe some of its saline particles, though in so small a quantity as not to be perceived, unless in these their depositories after a long tract of time. And if, on repeating the experiment, after another equal number of ages, it shall be found that the saltness is further increased with the same increment as before, than what is now proposed as hypothetical, would appear little less than demonstrative. But since this argument can be of no use to ourselves, it requiring very great intervals of time to come to our conclusion, it were to be wished that the ancient Greek and Latin authors had delivered down to us the degree of the saltness of the sea, as it was about two thousand years ago: for then it cannot be doubted but that the difference between what is now found and what then was, would become very sensible. I recommend it therefore to the Society, as opportunity shall offer, to procure the experiments to be made of the present degree of saltness of the ocean, and of as many

of these lakes as can be come at, that they may stand upon record for the benefit of future ages.

"If it be objected that the water of the ocean, and perhaps of some of these lakes, might at the first beginning of things, in some measure contain salt, so as to disturb the proportionality of the increase of saltness in them, I will not dispute it: but shall observe that such a supposition would by so much contract the age of the world, within the date to be derived from the foregoing argument, which is chiefly intended to refute the ancient notion, some have of late entertained, of the eternity of all things; though perhaps by it the world may be found much older than many have hitherto imagined."

It must be admitted, observes Dr. Thomson upon the above hypothesis, that this is an ingenious and plausible speculation; but it will not bear a rigid examination. We have no evidence whatever, that the sea was not salt at its original formation. Indeed there is presumption in favour of that opinion; because many of the animals which it contains cannot live in fresh water. Hence we must either admit that the sea remained for many ages uninhabited, or that it was salt at its first formation. But, granting that the sea was originally fresh, it would not follow that it became salt by evaporation, unless we were certain that the vapour which rises from the sea is absolutely destitute of salt. But we have evidence that this is not the case. Margraaff found salt in rain water, which must have been originally raised by evaporation, either from the sea or the land; and, if we suppose the latter, the supposition makes more strongly for the reality of the vapour from sea-water containing some salt. But even if this point were given up, still there is another consideration which would make it difficult or impossible to deduce any conclusions from the rate at which the saltness of the sea increases. It is true that salt is mixed, to a certain amount, with almost every mineral in nature, as follows from the galvanic experiments of Mr. Davy. But the proportion of it is very various in different places. Sometimes, as in Cheshire and in Poland, we find it deposited in prodigious quantities, so as to form beds of enormous thickness. In other cases it is loosely scattered, but in very inconsiderable quantities, in rocks and the soil. While in other cases it is so intimately mixed, that it cannot be separated by any

other method, with which we are acquainted, than the galvanic energy. Water flowing through minerals of such different natures must dissolve very different proportions of salt. In beds of the first kind, it may, in certain circumstances, become saturated with salt, and will always dissolve so much as to be entitled to the name of a salt spring. In beds of the second kind, it will dissolve only a very minute quantity of salt; and, in those of the third kind, if any such exist of any considerable extent, it will dissolve none at all. Hence waters, when they began to flow into the sea and into lakes, would contain very different proportions of salt, according to the nature of the country through which they flowed; and hence different lakes, and different parts of the sea, would possess different degrees of saltness, and would increase in saltness at very different rates. Finally, this increase of saltness of the sea, if it takes place at all, must do so with inconceivable slowness; for the specific gravity of sea-water has never been observed to increase since the first time that it ever was taken, which is more than a century ago.

[*Thomson. Phil. Trans.* 1715.]

SECTION VI.

On the Tides.

1. *Explanation of the received or Newtonian System.*

THE height of the surface of the sea at any given place is observed to be liable to periodical variations, which are found to depend on the relative position of the moon, combined in some measure with that of the sun. These variations are called tides; they were too obvious to escape the observation even of the ancients, who inhabited countries where they are least conspicuous: for Aristotle mentions the tides of the northern seas, and remarks that they vary with the moon, and are less conspicuous in small seas than in the ocean: Cæsar, Strabo, Pliny, Seneca, and Macrobius give also tolerably accurate accounts of them.

There are in the tides three orders of phenomena which are separately distinguishable: the first kind occurs twice a day, the second twice a month, and the third twice a year. Every day, about the time of the moon's passing over the meridian, or a certain number of hours later, the sea becomes elevated above its mean

height, and at this time it is said to be high water. The elevation subsides by degrees, and in about six hours it is low water, the sea having attained its greatest depression; after this it rises again when the moon passes the meridian below the horizon, so that the ebb and flood occur twice a day, but become daily later and later by about $50\frac{1}{2}$ minutes, which is the excess of a lunar day above a solar one, since $28\frac{1}{2}$ lunar days are nearly equal to $29\frac{1}{2}$ solar ones.

The second phenomenon is, that the tides are sensibly increased at the time of the new and full moon: this increase and diminution constitute the spring and neap tides; the augmentation becomes also still more observable when the moon is in its perigee, or nearest the earth. The lowest as well as the highest water is at the time of the spring tides; the neap tides neither rise so high nor fall so low.

The third phenomenon of the tides is the augmentation which occurs at the time of the equinoxes: so that the greatest tides are when a new or full moon happens near the equinox, while the moon is in its perigee. The effects of these tides are often still more increased by the equinoctial winds, which are sometimes so powerful as to produce a greater tide before or after the equinox, than that which happens in the usual course, at the time of the equinox itself.

These simple facts are amply sufficient to establish the dependence of the tides on the moon; they were first correctly explained by Newton as the necessary consequences of the laws of gravitation, but the theory has been still further improved by the labours of later mathematicians. The whole of the investigations has been considered as the most difficult of all astronomical problems; some of the circumstances depend on causes which must probably remain for ever unknown to us; and unless we could every where measure the depth of the sea, it would be impossible to apply a theory, even if absolutely perfect, to the solution of every difficulty that might occur. A very injudicious attempt has been made to refer the phenomena of the tides to causes totally different from these, and depending on the annual melting of the polar ice: the respectability of its author is the only claim which it possesses even to be mentioned; and a serious confutation of so groundless an opinion would be perfectly superfluous.

A detached portion of a fluid would naturally assume, by its mutual gravitation, a spherical form, but if it gravitate towards another body at a distance, it will become an oblong spheriod of which the axis will point to the attracting body: for the difference of the attraction of this body on its different parts will tend to separate them from each other in the greatest part of the sphere, that is, at all places within the angular distance of $79\frac{1}{2}°$ from the line passing through the attracting body, either in the nearer or in the remoter hemisphere; but to urge them towards the centre, although with a smaller force in the remaining part. Hence, in order that there may be an equilibrium, the depth of the fluid must be greatest where its gravitation, thus composed, is least; that is, in the line directed towards the attracting body, and it may be shown that it must assume the form of an oblong elliptic spheroid.

If the earth were wholly fluid, and the same part of its surface were always turned towards the moon, the pole of the spheroid being immediately under the moon, the lunar tide would remain stationary, the greatest elevation being at the points nearest to the moon and furthest from her, and the greatest depression in the circle equally distant from these points; the elevation being, however, on account of the smaller surface to which it is confined twice as great as the depression. The actual height of thi selevation would probably be about forty inches, and the depression twenty, making together a tide of five feet. If also the waters were capable of assuming instantly such a form as the equilibrium would require, the summit of a spheroid equally elevated would still be directed towards the moon, notwithstanding the earth's rotation. This may be called the primitive tide of the ocean: but on account of the perpetual change of place which is required for the accommodation of the surface to a similar position with respect to the moon, as the earth revolves, the form must be materially different from that of such a spheroid of equilibrium. The force employed in producing this accommodation may be estimated by considering the actual surface of the sea as that of a wave moving on the spheroid of equilibrium, and producing in the water a sufficient velocity to preserve the actual form. We may deduce, from this mode of considering the subject, a theory of the tides which appears to be more simple and satisfactory than any which has yet been publish-

ed: and by comparing the tides of narrower seas and lakes with the motions of pendulums suspended on vibrating centres, we may extend the theory to all possible cases.

If the centre of a pendulum be made to vibrate, the vibrations of the pendulum itself, when they have arrived at a state of permanence, will be performed in the same time with those of the centre; but the motion of the pendulum will be either in the same direction with that of the centre, or in a contrary direction, accordingly as the time of this forced vibration is longer or shorter than that of the natural vibration of the pendulum; and in the same manner it may be shown that the tides either of an open ocean or of a confined lake may be either direct or inverted with respect to the primitive tide, which would be produced if the waters always assumed the form of the spheroid of equilibrium, according to the depth of the ocean, and to the breadth as well as the depth of the lake. In the case of a direct tide, the time of the passage of the luminary over the meridian must coincide with that of high water, and in the case of an inverted tide with that of low water.

In order that the lunar tides of an open ocean may be direct, or synchronous, its depth must be greater than thirteen miles, and for the solar tides than fourteen. The less the depth exceeded these limits, the greater the tides would be, and in all cases they would be greater than the primitive tides. But in fact the height of the tides in the open ocean is always far short of that which would be produced in this manner; it is therefore improbable that the tides are ever direct in the open ocean, and that the depth of the sea is so great as thirteen miles.

In order that the height of the inverted or remote lunar tides may be five feet, or equal to that of the primitive tides, the depth of the open sea must be $6\frac{1}{2}$ miles; and if the height is only two feet, which is perhaps not far from the truth, the depth must be three miles and five-sevenths.

The tides of a lake or narrow sea differ materially from those of the open ocean, since the height of the water scarcely undergoes any variation in the middle of the lake; it must always be high water at the eastern extremity when it is low water at the western: and this must happen at the time when the places of high and low

water, with respect to the primitive tides, are equally distant from the middle of the lake.

The tides may be direct in a lake one hundred fathoms deep and less than eight degrees wide; but if it be much wider, they must be inverted. Supposing the depth a mile, they will be direct when the breadth is less than 25°; but if a sea, like the Atlantic, were fifty or sixty degrees wide, it must be at least four miles deep, in order that the time of high water might coincide with that of the moon's southing.

Hitherto we have considered the motion of the water as free from all resistance; but where the tides are direct, they must be retarded by the effect of a resistance of any kind; and where they are inverted, they must be accelerated; a small resistance producing, in both cases, a considerable difference in the time of high water.

Where a considerable tide is observed in the middle of a limited portion of the sea, it must be derived from the effect of the elevation or depression of the ocean in its neighbourhood; and such derivative tides are probably combined in almost all cases with the oscillations belonging to each particular branch of the sea. Mr. Laplace supposes that the tides, which are observed in the most exposed European harbours, are produced almost entirely by the transmission of the effect of the main ocean, in about a day and a half; but this opinion does not appear to be justified by observation; for the interval between the times of the high water belonging to the same tide, in any two places between Brest and the Cape of Good Hope, has not been observed to exceed about twelve hours at most; nor can we trace a greater difference by comparing the state of the tides at the more exposed situation of St. Helena, the Cape Verd Islands, the Canaries, the Madeiras, and the Azores, which constitute such a succession as might be expected to have indicated the progress of the principal tide, if it had been such as Mr. Laplace supposes. The only part of the ocean, which we can consider as completely open, lies to the south of the two great continents, chiefly between the latitudes 30° and 70° south, and the original tide, which happens in this widely extended ocean, where its depth is sufficiently uniform, must take place, according to the theory which has been advanced, at some time before the sixth

lunar hour. It sends a wave into the Atlantic, which is perhaps twelve or thirteen hours in its passage to the coast of France, but certainly not more. This tide, which would happen at the sixth lunar hour after the moon's transit, if there were no resistance, is probably so checked by the resistance, that the water begins to subside about the fourth, and in some seas even somewhat earlier, although in others it may follow more nearly its natural course. There is scarcely a single instance which favours the supposition of the time of high water in the open sea being within an hour of the moon's southing, as it must be if the depth were very great: so that neither the height of the tides nor the time of high water will allow us to suppose the sea any where quite so deep as four miles.

The tide entering the Atlantic appears to advance northwards at the rate of about five hundred miles an hour, corresponding to a depth of about three miles, so as to reach Sierra Leone at the eight hour after the moon's southing; this part of Africa being not very remote from the meridian of the middle of the south Atlantic ocean, and having little share in the primitive tides of that ocean.

The southern tide seems then to pass by Cape Blanco and Cape Bojador, to arrive at Gibraltar at the thirteenth hour, and to unite its effects with those of other tides at various parts of the coast of Europe.

We may therefore consider the Atlantic as a detached sea about 3500 miles broad and three miles deep; and a sea of these dimensions is susceptible of tides considerably larger than those of the ocean, but how much larger we cannot determine without more accurate measures. These tides would happen on the European coasts, if there were no resistance, a little less than five hours after the moon's southing, and on the coast of America, a little more than seven hours after; but the resistance opposed to the motion of the sea may easily accelerate the time of high water in both cases about two hours, so that it may be a little before the third hour on the western coasts of Europe and of Africa, and before the fifth on the most exposed parts of the eastern coast of America; and in the whole of the Atlantic, this tide may be combined more or less both with the general southern tide, and with the partial effects of local elevations or depressions of the bottom of the sea.

which may cause irregularities of various kinds. The southern tide is, however, probably less considerable than has sometimes been supposed, for, in the latitudes in which it must originate, the extent of the elevation can only be half as great as at the equator; and the Islands of Kerguelen's Land and South Georgia, in the latitudes of about 50° and 55°, have their tides delayed till the tenth and eleventh hours, apparently because they receive them principally from distant parts of the ocean, which are nearer to the equator.

On the western coasts of Europe, from Ireland to Cadiz, on those of Africa, from Cape Coast to the Cape of Good Hope, and on the Coast of America, from California to the streights of Magellan, as well as in the neighbouring islands, it is usually high water at some time between two and four hours after the moon's southing; on the eastern coast of South America between four and six, on that of North America between seven and eleven; and on the eastern coasts of Asia and New Holland between four and eight. The Society islands are perhaps too near the middle of the Pacific ocean to partake of the effects of its primitive tide, and their tide, being secondary, is probably for this reason a few hours later. At the Almirantes, near the eastern coast of Africa, the tide is at the sixth hour; but there seem to be some irregularities in the tides of the neighbouring islands.

The progress of a tide may be very distinctly traced from its source in the ocean into the narrow and shallow branches of the sea which constitute our channels. Thus the tide is an hour or two later at the Scilly Islands than in the Atlantic, at Plymouth three, at Cork, Bristol, and Weymouth four, at Caen and Havre six, at Dublin and Brighthelmstone seven, at Boulogne and Liverpool eight, at Dover near nine, at the Nore eleven, and at London bridge twelve and a half. Another portion appears to proceed round Ireland and Scotland into the North Sea; it arrives from the Atlantic at Londonderry in about three hours, at the Orkneys in six, at Aberdeen in eleven, at Leith in fourteen, at Leostoffe in twenty, and at the Nore in about twenty-four, so as to meet there the subsequent tide coming from the south. From the time occupied by the tide in travelling from the mouth of the English channel to Boulogne, at the rate of about fifty miles an hour, we may

calculate that the mean depth of the channel is about twenty-eight fathoms, independently of the magnitude of the resistances of various kinds to be overcome, which require us to suppose the depth from thirty to forty fathoms. In the great river of Amazons, the effects of the tides are still sensible at the streights of Pauxis, 500 miles from the sea, after an interval of several days spent in their passage up: for the slower progressive motion of the water no more impedes the progress of a wave against the stream, than the velocity of the wind prevents the transmission of sound in a contrary direction.

Such are the general outlines of the lunar tides; they are, however, liable to a great variety of modifications, besides their combination with the tides produced by the sun. When the moon is exactly over the equator, the highest part of the remoter, or inferior, as well as of the nearer or superior tides, passes also over the equator, and the effect of the tide in various latitudes decreases gradually from the equator to the pole, where it vanishes; but when the moon has north or south declination, the two opposite summits of the spheroid describe parallels of latitude, remaining always diametrically to each other. Hence the two successive tides must be unequal at every place except the equator, the greater tide happening when the nearer elevation passes its meridian: and the mean between both is somewhat smaller than the equal tides which happen when the moon passes the equator. This inequality is, however, much less considerable than it would be if the sea assumed at once the form of the spheroid of equilibrium; and the most probable reasons for this circumstance, are, first, that our tides are partly derived from the equatorial seas; secondly, that the effects of a preceding tide are in some measure continued so as to influence the height of a succeeding one; and, thirdly, that the tides of a narrow sea are less affected by its latitude than those of a wide ocean. The height of the sea at low water is the same whatever the moon's declination may be. There is also a slight difference in the tides, according to the place of the moon's nodes, which allows her declination to be greater or less, and this difference is most observable in high latitudes, for instance, in Iceland; since, in the neighbourhood of the poles, the tide depends almost entirely on the declination.

In all these cases, the law of the elevation and depression of each tide may be derived, like that of the vibrations of a pendulum and of a balance, from the uniform motion of a point in a circle. Thus, if we conceive a circle to be placed in a vertical plane, having its diameter equal to the whole magnitude of the tide, and touching the surface of the sea at low water, the point, in which the surface meets the circumference of the circle, will advance with a uniform motion, so that if the circle be divided into twelve parts, the point will pass over each of these parts in a lunar hour. It sometimes happens, however, in confined situations, that the rise and fall of the water deviates considerably from this law, and the tide rises somewhat more rapidly than it falls; and in rivers, for example in the Severn, the tide frequently advances suddenly with a head of several feet in height. These deviations probably depend on the magnitude of the actual displacement of the water, which in such cases bears a considerable proportion to the velocity of the tide, while in the open ocean a very minute progressive motion is sufficient to produce the whole elevation. The actual progress of the tides may be most conveniently observed, by means of a pipe descending to some distance below the surface, so as to be beyond the reach of superficial agitations, and having within it a float, carrying a wire, and indicating the height of the water on a scale properly divided.

We have hitherto considered the tides so far only as they are occasioned by the moon; but in fact the tides, as they actually exist, depend also on the action of the sun, which produces a series of effects precisely similar to those of the moon, although much less conspicuous, on account of the greater distance of the sun, the solar tide being only about two-fifths of the lunar. These tides take place independently of each other, nearly in the same degree as if both were single; and the combination resulting from them is alternately increased and diminished, accordingly as they agree or disagree, with respect to the time of high water at a given place; in the same manner as if two series of waves, equal among themselves, of which the breadths are as 29 to 30, be supposed to pass in the same direction over the surface of a fluid, or if two sounds similarly related be heard at the same time, a periodical increase and diminution of the joint effect will in either case be produced. Hence are derived the spring and neap tides, the effects of the sun and moon being united at the times of conjunction and opposition, or of the new and full

moon, and opposed at the quadratures, or first and last quarters. The high tides at the times of the equinoxes are produced by the joint operation of the sun and moon, when both of them are so situated as to act more powerfully than elsewhere.

The lunar tide being much larger than the solar tide, it must always determine the time of high and low water, which, in the spring and neap tides, remains unaltered by the effect of the sun; so that in the neap tides, the actual time of low water is that of the solar high water; but at the intermediate times, the lunar high water is more or less accelerated or retarded. The progress of this alteration may easily be traced by means of a simple construction. If we make a triangle of which two of the sides are two feet and five feet in length, the external angle which they form being equal to twice the distance of the luminaries, the third side will shew precisely the magnitude of the compound tide, and the halves of the two angles opposite to the first two sides the acceleration, or retardation, of the times of high water belonging to the separate tides respectively. Hence it appears that the greatest deviation of the joint tide from the lunar tide amounts to 11° 48′ in longitude, and the time corresponding, to 47 minutes, supposing the proportion of the forces to remain always the same; but in fact the forces increase in proportion as the cubes of the distances of their respective luminaries diminish, as well as from other causes; and in order to determine their joint effects, the length of the sides of the triangle must be varied accordingly. In some ports, from a combination of circumstances in the channel, by which the tides reach them, or in the seas, in which they originate, the influence of the sun and moon may acquire a proportion somewhat different from that which naturally belongs to them: thus at Brest, the influence of the moon appears to be three times as great as that of the sun; when it is usually only twice and a half as great.

The greatest and least tides do not happen immediately at the times of the new and full moon, but at least two, and commonly three tides after, even at those places which are most immediately exposed to the effects of the general tide of the ocean. The theory which has been advanced will afford us a very satisfactory reason for this circumstance; the resistance of fluids in general is as the square of the velocity, consequently it must be much greater for the lunar than for the solar tide, in proportion to the magnitude of the

force, and the acceleration of the lunar tide produced by this cause must be greater than that of the solar; hence it may happen that when the lunar tide occurs two or three hours after the transit of the moon, the solar tide may be three or four hours after that of the sun, so as to be about an hour later, at the times of conjunction and opposition, and the tides will be highest when the moon passes the meridian about an hour after the sun; while at the precise time of the new and full moon, the lunar tide will be retarded about a quarter of an hour by the effect of the solar tide.

The particular forms of the channels, through which the tides arrive at different places, produce in them a great variety of local modifications; of which the most usual is, that from the convergence of the shores of the channels, the tides rise to a much greater height than in the open sea. Thus at Brest the height of the tides is about 20 feet, at Bristol 30, at Chepstow 40, at St. Maloes 50; and at Annapolis Royal, in the Bay of Fundy, as much sometimes as 100 feet; although perhaps in some of these cases a partial oscillation of a limited portion of the sea may be an immediate effect of the attraction of the luminary. In the Mediterranean the tides are generally inconsiderable, but they are still perceptible; at Naples they sometimes amount to a foot, at Venice to more than two feet, and in the Euripus, for a certain number of days in each lunation, they are very distinctly observable, from the currents which they occasion. In the West Indies, also, and in the gulf of Mexico, the tides are less marked than in the neighbouring seas, perhaps on account of some combinations derived from the variations of the depth of the ocean, and from the different channels by which they are propagated.

In order to understand the more readily the effects of such combinations, we may imagine a canal, as large as the river of the Amazons, to communicate at both its extremities with the ocean, as to receive at each an equal series of tides, passing towards the opposite extremity. If we suppose the tides to enter at the same instant at both ends, they will meet in the middle, and continue their progress without interruption: precisely in the middle the times of high and low water belonging to each series will always coincide, and the effects will be doubled; and the same will happen at the points, where a tide arrives from one extremity at the same instant that an earlier or a later tide comes from the other; but at the intermediate

points the effects will be diminished, and at some of them completely destroyed, where the high water of one tide coincides with the low water of another. The tides at the port of Batsha in Tonkin have been explained by Newton from considerations of this nature. In this port there is only one tide in a day; it is high water at the sixth lunar hour, or at the moon's setting, when the moon has north declination, and at her rising, when she has south declination; and when the moon has no declination there is no tide. In order to explain this circumstance, we may represent the two unequal tides which happen in succession every day, by combining with two equal tides another tide, independent of them, and happening only once a day; then, if a point be so situated in the canal which we have been considering, that the effects of the two equal semidiurnal tides may be destroyed, those of the daily tides only will remain to be combined with each other; and their joint result will be a tide as much greater than either, as the diagonal of a square is greater than its side; the times of high and low water being intermediate between those which belong to the diurnal tides considered separately. Thus, in the port of Batsha, the greater tide probably arrives at the third lunar hour directly from the Pacific ocean, and at the ninth from the gulf of Siam, having passed between Sumatra and Borneo; so that the actual time of high water is at the sixth lunar hour. The magnitude of this compound tide is by no means inconsiderable; it sometimes amounts to as much as 13 feet.

Besides the variations in the height of the sea, which constitute the tides, the attractions of the sun and moon are also supposed to occasion a retardation in its rotatory motion, in consequence of which it is left a little behind the solid parts of the earth; and a current is produced, of which the general direction is from east to west. This current comes from the Pacific and Indian oceans, round the Cape of Good Hope, along the coast of Africa, then crosses to America, and is there divided and reflected southwards towards the Brazils, and northwards into the Gulf stream, which travels round the gulf of Mexico, and proceeds north eastwards into the neighbourhood of Newfoundland, and then probably eastwards and south eastwards once more across the Atlantic. It is perhaps on account of these currents that the Red Sea is found to be about 25 feet higher than the Mediterranean: their direction may possibly have been somewhat changed in the course of many ages, and with

it the level of the Mediterranean also; since the floor of the cathedral at Revenna is now several feet lower with respect to the sea than it is supposed to have been formerly, and some steps have been found in the rock of Malta, apparently intended for ascending it, which are at present under water.

[*Young.*

For other valuable explanations of the flux and reflux of the sea, the reader may consult the very excellent paper of Halley in the Philosophical Transactions, year 1697; the prize essays of Cavalleri, Bernouilli, Maclaurin, and Euler. Lalande, Traité du Flux et Reflux; and La Place, Méchanique Celéste. As also Dr. Robison's very excellent paper on this subject printed in the Encyclopedia Britannica; in which he observes, that the smallest solar retardation of the tides is to the greatest, as the difference of the solar and lunar influence is to their sum; that is, from Dr. Maskelyne's observations at St. Helena, as 37 to 87; whence the sun's effect is to that as 2 to 4.96.

2. *Hypothesis of St. Pierre, concerning the Tides, compared with the common Doctrine.*

By Samuel Woods, Esq.

THE tides are two periodical motions actuating the ocean (called the flux and reflux, or ebb and flow), which succeed each other alternately, at an interval of about six hours; the period of a flux and reflux being, upon an average, 12 hours 24 minutes, the double of which, 24 hours 48 minutes, corresponds to that of a lunar day, or the time elapsing between the moon's passing a meridian and coming to it again. These alternate elevations and depressions of the ocean so exactly correspond with the course of the sun and moon, as to time and quantity, that the influence of those luminaries has in all ages been considered as the cause of their production; but it was reserved for modern times to ascertain the principle of their laws, and to calculate, with precision, the effects produced by the different situations of the sun and moon, and the proportions of their power. This principle is no other than gravitation. It is evident that, if the earth were entirely fluid and quiescent, its particles, by their mutual gravity, would form the whole

mass into a perfect sphere: now, if any power be supposed to act on all the particles of this sphere with equal force, and in parallel directions, the whole mass would be moved together without experiencing any alteration in its figure. But this is not the case with respect to the moon's action on our globe: the power of gravity diminishes as the square of the distance increases, and therefore the waters on the side of the earth next the moon are more attracted by the moon than the central parts of the earth, and the central parts more attracted than the waters on the opposite side; and therefore the distance between the earth's centre and the waters on its surface under and opposite to the moon will be increased. For, suppose three bodies in the same line, if they are all equally attracted by any power, they will all move towards it with equal rapidity, their mutual distances continuing the same; but, if the attraction of this power is unequal, the body most forcibly attracted will move fastest, and their reciprocal distances will be proportionally increased: thus, the power of gravitation acting unequally on the three bodies, the distance of the first from the second, and of the second from the third, will be increased in proportion to the difference of the gravitating power at the distance of the three bodies respectively: now, suppose a number of bodies placed round the centre so as to form a fluid ring, unequally attracted by some power, the parts nearest and furthest from this power will have their distance from the centre increased, while the sides of this ring, being nearly equidistant from the power, the centre will not recede, but rather approach the centre, and form an ellipsis. To apply this reasoning to the case under consideration, while the earth, by its gravity, tends towards the moon, the water directly below her will swell and rise gradually; the water on the opposite side will recede from the centre (or, more properly, the centre will advance), and rise, or appear to rise, while the water at the sides is depressed, and falls below the former level: hence, as the earth revolves on its axis from the moon to the moon again in 24 hours 50 minutes, there will be two tides of ebb and two of flood in that period. In consequence of the earth's motion on her axis, the most elevated part of the water is carried beyond the moon in the direction of the rotation, and continues to rise after it has passed directly under the moon, not attaining its greatest elevation till it has got about half a quadrant further. It continues also

to descend, after it has passed at 90° distance from the point below the moon, to a like distance of about half a quadrant; and therefore in open seas, where the water flows freely, the time of high water does not exactly coincide with the time of the moon's coming to the meridian, but is some time after. Besides, the tides do not always answer to the same distance of the moon from the meridian, since they are variously affected by the sun's action, which brings them on sooner when the moon is in her first and third quarters, and keeps them back later when she is in her second and fourth: because, in the former case, the tide raised by the sun alone would be earlier than the tide raised by the moon: in the latter case, later.

We have hitherto considered the moon as the principal agent in producing tides, but it is obvious that the inequality of the sun's action must produce a similar effect; so that, in reality, there are two tides every natural day occasioned by the sun, as well as two tides every lunar day occasioned by the moon, and subject to the same laws: on account, however, of the sun's immense distance, his action is considerably inferior to that of the moon. By comparing the spring and neap tides at the mouth of the Avon, below Bristol, Sir Isaac Newton calculates the proportion of the moon's force to the sun's as nine to two nearly. Dr. Horsley, in his edition of the Principia, estimates it at 5,0469 to 1; and, considering the elevation of the waters by this force as an effect similar to the elevation of the equatorial above the polar parts of the earth, it will be found that the moon is capable of producing an elevation of about ten feet, the sun of about two feet; which corresponds pretty nearly to experience.

In order to understand the cause of spring and neap tides, we must consider, that the moon, revolving round the earth in an elliptic orbit, approaches nearer and recedes further from it, than her mean distance, in every revolution or lunar month. When nearest, her attraction is strongest, and *vice versâ*: when both luminaries are in the equator, and the moon in perigeo, the tides rise highest, particularly at opposition and conjunction: at the change, when the attractive forces of the sun and moon are combined, the tide is raised to a greater height: at the full, when the moon raises the tide under and opposite to her, the sun, acting in the same line, raises the tides under and opposite to him, whence their conjunct

effect is the same as at the change, and in both cases occasions what we call spring tides: but at the quarters, the sun's action diminishes the effect of the moon's action, so that they rise a little under and opposite the sun, and fall as much under and opposite the moon, these two luminaries acting obliquely on each other, and producing what is called neap tides.

The spring tides, however, do not happen precisely at the full and change of the moon, nor the neap tides at the quarters, but about two days later. In this, as in many other cases, the effects are not greatest, or least, when the immediate influence of the cause is greatest or least: as, for instance, the greatest heat of summer is not at the time of the solstice, but some weeks after; and if the actions of the sun and moon should be suddenly suspended, the tides would continue for some time in their usual course. The variations of the moon's distance from the earth produce a sensible difference in the tides. When the moon approaches the earth, her action on every part increases, and the differences of her action increase in a higher proportion as the moon's distances decrease. According to Sir Isaac Newton, the tides increase as the cubes of the distances decrease; so that the moon, at half her distance, would produce tides eight times as great. The sun being nearer the earth in winter than in summer, the spring tides are highest, and the neap tides lowest, about the time of the equinoxes, a little after the autumnal and before the vernal; and, on the contrary, the spring tides lowest and the neap tides highest at the solstices, when the sun is most distant from the equator. When the moon is in the equator, the tides are equally high in both parts of the lunar day; but as the moon declines towards either pole, the tides are alternately higher and lower at places having north or south latitude: while the sun is in the northern signs, the greater of the two diurnal tides in our climates is that arising from the moon above the horizon: when the sun is in the southern signs, the greatest is that arising from the moon below the horizon. Thus the evening tides in summer are observed to exceed the morning tides, and in winter the morning tides exceed the evening tides: the difference at Bristol is found to be fifteen inches, at Plymouth twelve. It would be still greater, but that a fluid always retains an impressed motion for some time, and consequently the preceding tides always affect those that follow.

If the earth were covered all over with the sea to a great depth, the tides would be regularly subservient to these laws; but various causes combine to produce a great diversity of effect, according to the peculiar situation and circumstances of places, shoals, fords, and straits: thus, a slow and imperceptible motion of a large body of water, suppose two miles deep, will be sufficient to elevate its surface ten or twelve feet in a tide's time; whereas, if the same quantity of water is forced through a narrow channel forty or fifty fathoms deep, it produces a very rapid stream, and of course the tide is found to set strongest in those places where the sea grows narrowest, the same quantity of water being constrained to pass through a smaller passage, as in the straits between Portland and Cape la Hogue in Normandy; and it would be still more so between Dover and Calais, if the tide coming round the island did not check it.

The shoalness of the sea and the intercurrent continents are the reasons why the tides in the open ocean rise but to very inconsiderable heights, when compared to what they do in wide-mouthed rivers opening in the direction of the stream of the tide; and that high water is some hours after the moon's appulse to the meridian, as it is observed upon all the western coast of Europe and Africa from Ireland to the Cape of Good Hope; in all which a south-west moon makes high water; and the same is said to be the case on the western coast of America: so that tides happen to different places at all distances of the moon from the meridian, and consequently at all hours of the day.

To allow the tides their full motion, the space in which they are produced ought to extend from east to west 90° at least; such being the distance between the places most raised and depressed by the moon's influence. Hence it appears that such tides can only be produced in large oceans, and why those of the Pacific exceed those of the Atlantic ocean: hence also it is obvious why the tides in the torrid zone between Africa and America, where the ocean is narrower, are exceeded by those of the temperate zones on either side: and hence we may comprehend why the tides are so small in islands at a great distance from the shores, since the water cannot rise on one shore without descending on the other; so that at the intermediate islands it must continue at a mean height between its elevations on those shores

The tide produced on the western coast of Europe corresponds to this theory. Thus, it is high water on the western coasts of Ireland, Spain, and Portugal, about the third hour after the moon has passed the meridian; from thence it flows into the adjacent channels, as it finds the easiest passage. One current, for example, runs up by the south of England, and another by the north of Scotland; taking considerable time to move all this way, and occasioning high water sooner in the places at which it first arrives, and begins to fall at these places while the current is proceeding to others further distant in its course. On its return it is unable to raise a tide, because the water runs faster off than it returns, till, by the propogation of a new tide from the ocean, the current is stopt, and begins to rise again. The tide propagated by the moon in the German ocean, when she is three hours past the meridian, takes twelve hours to come from thence to London bridge; so that, when it is high water there, a new tide has already attained its height in the ocean, and in some intermediate place it must be low water at the same time. When the tide runs over shoals, and flows upon flat shores, the water is elevated to a greater height than in open and deep oceans that have steep banks, because the force of its motion is not broken upon level shores till the water has attained a greater height. If a place communicates with two oceans, or by two different openings with the same ocean, one of which affords an easier and readier passage than the other, two tides may arive at this place in different times, which, interfering together, may produce a great variety of phænomena.

At several places it is high water three hours before the moon comes to the meridian: but that tide which the moon drives, as it were, before her, is only the tide opposite to that produced by her when nine hours past the opposite meridian.

It would be tedious to enumerate all the particular solutions easily deducible from these doctrines: as, why lakes and seas, such as the Caspian and the Mediterranean, the Euxine and the Baltic, have little or no sensible tides; since, having no communication, or being connected by very narrow inlets with the great ocean, they cannot receive or discharge water sufficient to alter their surface sensibly. In general, when the time of high water at any place is mentioned, it is to be understood on the days of new and full moon: the times of high water in any place fall at nearly

the same hours after a period of about fifteen days, or between one spring tide and another.

This theory, however, is not without objections and difficulties; which has encouraged a Frenchman of some eminence, St. Pierre, to frame a new and singular hypothesis, ascribing all the phæno- mena of the tides to the periodical effusions of the polar ices. I shall first mention the most material facts and considerations which appear to militate against the common theory, as stated by St. Pierre; and I shall then endeavour to explain the theory he has substituted (which it has cost me some pains to collect, abstract, and arrange), as nearly as possible in a literal translation of his own language.

It is said that, if the moon acted by her attraction, her influence must extend to the Mediterranean, the Baltic, the Caspian, and the vast lakes of North America, in some degree at least; but all these have no sensible tides *. This tranquillity renders her attraction liable to suspicion; and we shall, perhaps, find that the greatest part of the tides in the ocean have nothing more than an apparent relation either to her influence or her course.

The phases of the moon do not correspond all over the globe with the movements of the seas. On our coasts the flux and reflux follow the moon rather than her real motion: in various places they are subject to different laws, which obliged Newton to admit (chap. 25,) "that in the periodical return of the tides there must be some other mixed cause, hitherto undiscovered."

The currents and tides in the vicinity of the polar circle come from the pole, as appears from the testimony of Fred. Martens, who asserts, that the currents amidst the ices set in towards the south; but adds, that he can state nothing with certainty respecting the flux and reflux of the tides.—*Voyage towards the North Pole*, 1671.

Henry Ellis observed that the tides in Hudson's bay came from the north, and were accelerated as the latitude increased. It is impossible these tides should come from the line or the Atlantic. He ascribes them to a pretended communication with the South

* The Caspian sea is about 860 miles long, and, in one place, 260 miles broad: there are strong currents, but no tides.

There is no regular flux and reflux in the Baltic.

In some particular spots of the Mediterranean there is a small tide.

Sea. At Waigat's Straits these north tides run at the rate of eight or ten leagues an hour. He compares them to the sluice of a mill. —*Voyage to Hudson's Bay*, 1746.

Linscotten, in 1594, made nearly the same remarks, and observes that in Waigat's Straits the water was only brackish. He says the tides come from the east with great velocity, bringing with them large islands of ice.

W. Barents (1595) confirms this account.

All these effects can be produced by nothing else than the effusion of ices surrounding the pole. These ices, which melt and flow with such rapidity in the northern parts of America and Europe about the month of July and August, greatly contribute to our high equinoctial tides; and when these effusions cease in October, our tides begin to diminish.

If the tides depend on the action of the sun and moon on the equator, they ought to be much more considerable towards the focus of their movements than any where else. But this is contrary to fact, (Dampier says). From Cape Blanc, from the third to 30′ south lat. the flux and reflux of the sea does not exceed two feet. The tides in the East Indies rise not above a foot; near the poles they rise 20 to 25 feet.

In the road of the island Massafuero (33° 46′ south lat. 80° 22′ west long.) the sea runs twelve hours north, and then flows back twelve hours south: its tides, therefore, run towards the line.—*Byron, April* 1765.

At English Creek, on the coast of New Britain (5° south lat. 152° west long.) the tide has a flux and reflux once in twenty four hours.—*Carteret, August* 1767.

At the Bay of Isles, in New Zeland (35° south lat.), the tides set in from the south.—*Cook, Dec.* 1769.

At Endeavour river, in New Holland, neither the flood or ebb tides were considerable, excepting once in twenty-four hours.—*June,* 1770.

At Christmas Harbour, in Kerguelen's Land, the flood came from the south-east, running two knots an hour.—*Cook, Dec.* 1766. It appears to have been regular and diurnal, *i. e.* a tide of twelve hours. The tide rises and falls about four feet.

At Otaheite the tides seldom rise more than twelve or fourteen inches; and it is high water nearly at noon, as well at the quar-

ters as at the full and change of the moon *. It is evident, from a table of these tides for twenty-six days, that there was but one tide a day; and this, during the whole time, was at its mean height between eleven and one. These tides, therefore, can have no relation to the phases of the moon.

Let us now take a cursory view of the effects produced by the tides in the northern part of the South Sea. At the entrance of Nootka it is high water, on the days of new and full moon, at twenty minutes past twelve: the perpendicular rise and fall eight feet nine inches; which is to be understood of the day tides, and those which happen two or three days after the full and change. The night tides rise nearly two feet higher †. These semidiurnal tides differ from ours in taking place at the same hour, and exhibiting no sensible rise till the second or third day after the full moon: all which is perfectly inexplicable on the lunar hopothesis.

These northern tides of the South Sea, remarked in April, become, in higher latitudes, stronger in May, and still stronger in June; which cannot be referred to the moon's course then passing into the southern hemisphere, but must be ascribed to the sun's course passing into the northern hemisphere, and proceeding, as its heat increases, to fuse the ices of the north pole: besides, the direction of these northern tides towards the line constitutes a complete confirmation that they derive their origin from the pole.

At the entrance of Cook's River there was a strong tide setting out of the inlet at the rate of three or four knots an hour: higher up in the inlet, at a place four leagues broad, the tide ran with prodigious violence at the rate of five knots an hour. Here the marks of a river displayed themselves, the water proving considerably fresher ‡.

What Cook calls a river, is nothing but a real northern sluice, through which the polar effusions are discharged into the ocean. Middleton § found between lat. 65° and 66°, a considerable inlet running west, which he calls Wager's River; and, after repeated trials of the tides for three weeks, found the flood constantly coming from the east. This is another of the northern slucies.

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* Cook, Dec. 1777. † Cook, April 1778. ‡ Cook, May 1778.

§ Voyage to Hudson's Bay, 1741 and 1742.

In Karahakooa Bay, Sandwich Islands, the tides are very regular, ebbing and flowing six hours each alternately *.

At the town of St. Peter and Paul, in Kamschatka, the tides are very regular every twelve hours †.

Mr. Wales acknowledges that the tides observed in the middle of the great Pacific ocean fall short full two-thirds of what might have been expected from calculation ‡.

The course of the tides towards the equator in the South Sea; their retardations and accelerations on these shores; their directions, sometimes eastward, sometimes westward, according to the monsoons; finally, their elevation, which increases in proportion as we approach the poles, and diminishes in proportion to the distances from it, even between the tropics, demonstrate that their focus is not under the line. The cause of their motions depends not on the attraction or pressure of the sun and moon on that part of the ocean, for their forces would undoubtedly act there with the greatest energy, and in periods as regular as the course of the two luminaries.

Why, then, are the tides between the tropics so feeble and so much retarded under the direct influence of the moon?

Why does the moon, by her attraction, give us two tides every twenty-four hours in the Atlantic ocean, and produce only one in many parts of the South sea, which is incomparably broader?

Why do the tides take place there constantly at the same hours, and rise to a regular height almost all the year round?

Why do some rise at the quarters just the same as at the full and change?

Why are they always stronger as you approach the poles, and frequently set in toward the line, contrary to the principle of lunar impulsion?

These problems, which it is impossible to explain by the lunar theory, admit an easy solution on the hypothesis of the alternate fusion of the polar ices.——

Such are the most material objections adduced to invalidate the lunar theory. How far they are conclusive, shall be left to future investigation.

But St. Pierre is not content with demolishing the old structure;

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* Clerke, March 1779. † Clerke, Oct. 1779.

‡ Introduction to Cook's last Voyage.

he has judged proper to erect a new one; and a fair exposition of this system will enable us to determine, by comparison, to which we shall give our suffrage.

It is well known that Sir Isaac Newton and Cassini differed in their opinion respecting the figure of the earth: the former conceiving it to be an oblate spheroid, flattened at the poles; the latter contending it must be oblong, or elongated at the poles. To ascertain this point, some of the most celebrated mathematicians of Europe were appointed to determine, by actual measurement, the length of a degree both at the equator and at the pole. They found that the polar degrees exceeded the equatorial, and concluded they must consequently be parts of a larger circle, and, of course, that the earth was flattened at the poles. This was universally considered as decisive of the question, till the genius of M. St. Pierre detected a gross and palpable error in the calculation, which had escaped their accurate knowledge and penetration: but, as the elongation of the poles constitutes a leading feature in the new theory, I shall give it a more detailed examination.

This polar elongation, as he conceives, is supported by four direct and positive proofs:—the first geometrical, upon which he lays the greatest stress, and upon which he has staked his reputation; the second, atmospherical; the third, nautical; the fourth, astronomical: of all which in order.

The first, or geometrical proof, is what he calls a demonstration founded on the measurement of the earth, and admitting the polar degrees to exceed the equatorial; here follows the demonstration: If you place a degree of the meridian at the polar circle on a degree of the same meridian at the equator, the first degree, which measures 57,422 fathoms, will exceed the second, which is 56,748 fathoms, by 674; consequently, if you apply the arc of the meridian contained within the polar circle, being 47°, to an arc of 47° of the same meridian at the equator, it would produce a considerable protuberance, its degrees being greater.

To render this more apparent, let us always suppose that the profile of the earth, at the poles, is an arc of a circle containing 47°; is it not evident, if you trace a curve on the inside of this arc, as the academicians do when they flatten the earth at the poles, that it must be smaller than the arc within which it is described, being contained in it? And the more this curve is flattened the smaller

it becomes. Of consequence, the 47° of this entire curve will be individually smaller than the 47° of the containing arc. But as the degrees of the polar curve exceed those of the arc of a circle, it must follow that the whole curve is of greater extent than the arc of a circle: now to be of greater extent it must be more protuberant: the polar curve, of consequence, forms a lengthened ellipsis. Q. E. D.

It must be acknowledged that this demonstration is very perspicuous and convincing. How the most celebrated academicians and mathematicians, for nearly half a century, could have overlooked a proposition so plain and simple, can only be ascribed, in the opinion of St. Pierre, to their obstinate and inveterate prejudices. He pursues his victory in a strain of vain and indecent exultation, which would dishonour a more respectable cause; but, perhaps, a little attention will induce us to doubt at least whether the charge of gross ignorance may not, with justice, be retorted on their accuser.

It would have been indeed extraordinary, if men of science had been absurd enough to imagine that a larger arc might be included in a less; but they might suppose, with propriety and justice, that the smaller arc of a larger circle can be included in the larger arc of a smaller circle, which, in the present instance, appears to be the case. In measuring a degree on the meridian, a certain spot is fixed upon, where the elevation of the polar star is taken by a quadrant; from this spot they proceed in a direct line north, till the quadrant indicates an additional elevation of one degree. In proportion as this degree constitutes a part of a larger or smaller circle, a greater or less portion of ground will be passed over before the desired elevation is observed; and the measurement of this ground unequivocally decides whether this degree is part of a larger or smaller circle. In this case the measurement is admitted, but the conclusion denied. St. Pierre seems to have supposed, that the academicians divided the polar arc into 47 parts, and then measured one of these parts: a thing impracticable and ridiculous. The fact is, that the polar arc, which, if the earth were a perfect sphere, would contain 47°, does not actually contain so many, but perhaps about 46° of a larger circle; and if the polar degrees are parts of a larger circle, as they certainly are, it is demonstrably evident that the real arc must be contained within the spherical arc, and, consequently, that the earth is flattened at the poles.

I now proceed to state the three remaining proofs adduced by

St. Pierre in corroboration of the demonstration I have just noticed; but, as I conceive myself to have fully disproved the, geometrical evidence, I shall not trouble you with an attempt to invalidate these subsidiary confirmations.

The second proof (says he) is atmospherical. It is well known that, in proportion as you ascend a mountain, the mercury in the barometer subsides: now the mercury sinks in the barometer in proportion as you advance northward. The weight of one line of mercury at Paris is equivalent to an elevation of 10 fathom and 5 feet, whereas in Sweden it is equivalent to 10 fathom 1 foot 6 inches only; and of course the ground of Sweden must be higher. From a series of observations made by Captain Cook in the southern hemisphere in 1773 to 1775, we perceive the mercury scarcely ever rises higher than 29 inches beyond the 60th degree of south latitude, and mounted almost always to 30 inches and even higher in the vicinity of the torrid zone; which proves that the barometer falls as you recede from the line, and that both poles are elongated.

The third proof it nautical, arising from the annual descent of the ices toward the line, impelled by currents proceeding alternately from each pole during their respective summers, immense mountains of ice being frequently seen by navigators in low latitudes.

The fourth proof is astronomical. Childrey (an English author of note) supposes, says M. St. Pierre, that the earth at the poles is covered with ice to such a height as to render its figure sensibly oval. Kepler says that the eclipse of the moon on the 26th September 1624, like the one observed by Tycho Brahè in 1588, which was total, and very nearly central, differed widely from the calculation: for, not only the duration of total darkness was extremely short, but the rest of the duration, previous and posterior to the total obscuration, was still shorter, as if the figure of the earth was elliptical, having the smallest diameter under the equator, and the greater from pole to pole.

Navigators in the north have always seen the elevation of the sun above the horizon greater the nearer they approach the poles. It is impossible to ascribe these optical effects to atmospherical refraction.

Barents, on the 24th of January, in Nova Zembla, saw the sun 15 days sooner than he expected, which would give a refraction of

$2\frac{1}{2}°$; a thing impossible, and the circumstance can be ascribed to no other cause than his real elevation.

St. Pierre cuts the difficulty arising from the different vibrations of the pendulum, by observing that they are liable to a thousand errors.

The elongation of the poles being thus demonstrated, the current of the seas and tides follows as a natural and necessary consequence.

Let us now consider the extent of the polar ices, and the powers capable of effecting their solution.

The polar ices in the winter proper to each hemisphere are from six to seven thousand leagues in circumference; but in their summer, from two to three thousand.

The ices and snows form in our hemisphere, in January, a cupola, the arch of which extends more than two thousand leagues over the two continents, with a thickness of some lines in Spain, some inches in France, several feet in Germany, many fathoms in Russia, and beyond the 60° of north latitude of some hundred feet. Some ice islands were seen by Ellis from fifteen to eighteen hundred feet above the level of the sea, and they probably go on increasing to the pole to a height indeterminable. Hence the enormous aggregation of water, fixed by the cold of winter in our hemisphere, above the level of the ocean, is clearly perceptible; and to the periodical fusion of these vast masses the general movement of the seas and tides is justly ascribable. The ices at the south pole exceed in quantity those at the north; and two such bodies of ices, alternately accumulated and dissolved, at the two poles, must occasion a very perceptible augmentation of its waters at their return to it by the action of the sun, and a great diminution by their reduction to ice when the sun retires. It has been calculated that the earth and sea covered with ice, may be equalled to 1-10th of the whole ocean, and the height of the polar ices is at least 600 feet; a mass which in melting must add 1-10th, that is 60 feet, to the level of the ocean.

Nature has distributed sandy zones to assist, at the proper season, in accelerating the fusion of the polar ices. The winds in summer convey the igneous particles with which these zones are filled towards the poles, where they assist the sun's action on the ices.

The moon also dissolves ice by the humidity of the atmosphere. When the moon shines in winter nights in all her lustre it freezes very sharply, because the north wind checks the evaporating influence of the moon: but if the wind is stilled ever so little, you see the heavens covered with vapours which exhale from the earth, and you find the atmosphere softened.

Nature having determined to indemnify the poles for the sun's absence, makes the moon pass toward the pole, which the sun abandons: she crystallises, and reduces into brilliant snows, the waters which cover it: she renders its atmosphere more refractive, that the sun's presence may be detained longer in it, and restored sooner to it: and hence also there is reason to conclude she has drawn out the poles of the earth in order to bestow on them a longer participation of the sun's influence. We may judge from analogy the general effect of the tides: a source discharging itself into a bason produces at the sides of that bason a backward motion or counter current, which carries straws and other floating substances up towards the source.

Charlevoix (Hist. of New France) tells us that, though the wind was contrary, he sailed at the rate of eight leagues a day up the lake Michigan, against its general current, by the assistance of its lateral counter-currents

M. de Crevcœur assures us, that in sailing up the Ohio, along its banks he made 422 miles in fourteen days, or ten leagues a-day, by means of the counter-currents, which have always a velocity proportional to that of the principal current.

The particular effects observed in lakes and rivers communicating with icy mountains, illustrate the nature of the polar effusions. A kind of flux and reflux in the lake of Geneva, during summer and towards the evening, is observable, occasioned by the melting of the snows, which fall into it after noon in greater quantities than at other seasons of the day. The intermittence of certain fountains is ascribable to the same cause. The frequent and rapid fluxes (ten or twelve times a day) of the Euripus, the strait separating Bœotia from Eubœa, arise from the same source.

The currents of the ocean are reducible to two general ones: one, during our summer, from the north pole, in a south direction; the other, during our winter, proceeding northward from the south pole.

Dampier lays it down as a principle, founded on many experiments, that currents are scarcely ever felt but out at sea, and tides upon the coasts.

The polar effusions, which are the tides of the north and east to those who dwell in the vicinity of the pole, or in bays communicating with it, take their general course to the middle of the channel of the Atlantic ocean, attracted toward the line by the diminution of the waters, which the sun is incessantly evaporating. They produce by their general current two contrary currents or collateral whirlpools similar to those produced by rivers on their banks, and the tides may be considered as vortices of the general current of the Atlantic ocean.

The general current, which flows from our pole in summer with so much rapidity, and which is so violent towards its source, crosses the equinoctial line, its flux not being stemmed by the effusions of the south pole, at that season consolidated into ice; it extends beyond the Cape of Good Hope, and being directed east, by the position of Africa and Asia, forces the Indian ocean into the same direction, and may be considered as the prime mover of the western monsoon, which takes place in the Indian seas in April, and ends in September.

The general current, issuing during our winter from the south pole, restores the Indian ocean to its natural motion west; crosses, in its turn, the equinoctial line, penetrates into our Atlantic ocean, directs its motion north by the position of America, and produces various changes in our tides. All the bays, creeks, and mediterraneans of southern Asia, such as the gulphs of Siam and Bengal, the Persian gulph, the Red sea, &c. are directed relatively to these currents north and south so as not to be stemmed by them; as all the bays and mediterraneans of Europe, as the Baltic, the English channel, the bay of Biscay, the Mediterranean sea, Baffin's bay, Hudson's bay, the gulph of Mexico, and many others, are directed relatively to these currents east and west; or, to speak with more precision, the axes of all the openings of the land in the old and new world are perpendicular to the axes of these general currents, so that their mouth only is crossed by them, and their depth is not exposed to the impulsions of the general movements of the ocean.

That these currents are not the offspring of my own imagination,

but actually such as I have described them, will appear from various testimonies. Froger says that in Brazil the currents follow the sun, running southward when he is south, and northward when he is north. In the summer of the southern hemisphere, the tides set in northward (*Schouten, Jan.* 1661), but in winter run southward and come from the north (*Fraser, May* 1712). C. Columbus set sail from the Canaries the beginning of September, and steered to the west; he found, during the first days of his voyage, that the currents carried him to the north-east; when he had advanced 200 or 300 leagues from land, he perceived their direction was southward: finally, as he approached the Lucayo islands, he again found the current setting in north.

The nautical observations of Cook demonstrate that the currents of the Atlantic ocean are alternate and half-yearly like those of the Indian ocean. The beans called Oxeyes, which grow only in the West Indies, are every year thrown up on the coast of Ireland, 1200 leagues distant. Seeds and turtles are brought to the Hebrides from the West Indies and America; and the mast of the Tilbury man of war, burnt at Jamaica, was found on these coasts: the current which wafts these along proceeds in a north direction, and proves that the Atlantic current comes from the south, and sets in north during our winter. The currents of the north annually convey, in summer, toward the south, long banks of floating ices of very considerable depth and elevation, which run aground as far south as the banks of Newfoundland.

Rennefort (June 20, 1666), near the Azores (in lat. 40° to 45°), saw the broken masts, sailyards, &c. wrecked in the engagement which lasted four days between the English and Dutch, from June 11 to 15: this naval combat took place 12 miles to the north-west of Ostend, about 51° north. The currents from the north had therefore wafted them in nine days 11° south, besides a considerable progress westward.

The general current issuing from the south pole divides into two branches; one, setting in towards the Atlantic ocean, penetrates even to its northern extremity. This part, straitened by the prominent parts of Africa and America, forms on the coast two counter currents, which proceed in opposite directions. One of these currents runs east, along the coast of Guinea, to the fourth degree of south latitude; the other takes its departure from Cape St. Augus-

tin, proceeding south-west, along Brasil, to Maire's Straits. In the middle of the Atlantic ocean, beyond the strait formed by the two continents, this general branch pushes on north, and advances to the north extremities of Europe and America, bringing us twice every day along our coasts the tides of the south, which are the half daily effusions of the two sides of the south pole. The other branch takes a direction south of Cape Horn, rushes into the South Sea, produces the monsoon in the Indian ocean, and, having made the tour of the globe, unites itself by the Cape of Good Hope to the general current which enters the Atlantic ocean.

In our summer, commencing toward the end of March, when the sun retires from the southern hemisphere, and proceeds to warm the north, the effusions of the south pole are stayed, those of our pole begin to flow, and the currents of the ocean change throughout every latitude. The general current of our seas divides also into two branches; the first deriving its source from Waigats, Hudson's Bay, &c. flows with the rapidity of a sluice, descends through the Atlantic ocean, crosses the line, and, finding itself confined at the same strait of Guinea and Brasil, forms two lateral counter currents setting in north: these counter currents produce, on the coasts of Europe, the tides which appear to come from the south. The general current advances south, arrives about the month of April at the Cape of Good Hope, and renders the passage round this cape so difficult to vessels returning from India at this season; about the middle of May it reaches the coasts of India, produces the west monsoon, and, having encompassed the globe, proceeds to Cape Horn, re-ascends the coasts of Brasil, and creates a current terminating at Cape St. Augustin.

The other general branch, which receives much less of the icy effusions, issues between the continents of Asia and America, and descends to the South sea, where it is re-united to the first branch. The ocean accordingly flows twice a year round the globe in opposite spiral directions, taking its departure alternately from each pole, and describes on the earth the same course which the sun does in the heavens.

The course of our tides towards the north in winter is not an effect of the lateral counter currents of the Atlantic ocean, but of the general current of the south pole, which runs north. In this direction almost throughout it passes from a wider space into a nar-

rower, and carries before it at once the whole mass of the waters of the Atlantic ocean, without permitting a single column to escape either to the right or left. However, if it meet a cape or strait to oppose its course, it would form there a lateral current, as at Cape St. Augustin, and in Africa about 10° N. lat.; for in the summer of the south pole the currents and tides return south on the American, and east on the African side, the whole length of the gulph of Guinea, in contradiction to all the laws of the lunar system.

From these polar effusions the principal phænomena of the tides may be explained. It will be evident, for example, why those of the evening should be stronger in summer than those of the morning; because the sun acts more powerfully by day than by night on the ices of the pole on the same meridian as ourselves: and also why our morning tides in winter rise higher than those of the evening, and why the order of our tides changes every six months; because, the sun being alternately towards both poles, the effect of the tides must be opposite, like the causes which produce them. At the solstices the tides are lower than at any other season of the year, and those likewise are the seasons when there is most ice on the two poles, and consequently least water in the sea: the reason is obvious, the winter solstice is with us the season of the greatest cold; of course there is the greatest possible accumulation of ice on our pole and hemisphere. At the south pole it is indeed the summer solstice; but little ice is then melted, because the action of the greatest heat is not felt there as with us, till the earth has an acquired heat superadded to the sun's action, which takes place six weeks following the summer solstice.

At the equinoxes, on the contrary, we have the highest tides; and these are precisely the seasons when there is least ice at the two poles, and of course the greatest quantity of water in the ocean. At our autumnal equinox in September, the greatest part of the ices of the north pole is melted, and those of the south pole begin to dissolve. The tides in March rise higher than those in September, because it is the end of summer to the south poles which contains much more ice than ours, and consequently sends a greater mass of water to the ocean.

I shall say nothing (he proceeds) of the intermittence of the polar

effusions, which produce on our coast two fluxes and two refluxes nearly in the same time that the sun, making the circuit of the globe, alternately heats two continents and two oceans, that is, in the space of twenty-four hours, during which his influence twice acts and is twice suspended; nor shall I speak of the retardation, which is nearly three quarters of an hour every day, and which seems regulated by the different diameters of the polar cupola of ice, whose extremities, melted by the sun, diminish and retire from us every day, and whose effusions must consequently require more time to reach the line, and to return from the line to us. Nor shall I dwell on the other relations these polar periods have to the phases of the moon, especially when she is at full; for her rays possess an evaporating heat, as the late experiments at Rome and Paris fully demonstrate; much less shall I involve myself in a discussion of the tides of the south pole, which in summer in the open sea come in vast surges from the south and the south-west. There are two tides every day; because the sun warms by turns, every twenty-four hours, the east and west side of the pole in fusion. Precisely the same effect takes place in lakes situated in the vicinity of icy mountains, which have a flux and reflux in the day-time only. But it cannot be doubted that, if the sun warmed, during the night, the other side of these mountains, they would produce another flux and reflux; and consequently two tides in twenty-hours, like the ocean.

We are not to imagine that every tide is a polar effusion of the particular day on which it happens, but an effect of the series of polar effusions; so that the tide which takes place on our coasts to-day, is perhaps part of that which took place six weeks ago. But here, too, must we admire the harmony of nature: the evening and morning tides take place on our coasts as if they issued that very day from the higher and lower part of our hemisphere; and the tides of summer are precisely opposite to the tides of winter, as are the tides from whence they flow; our evening tides in summer, and our morning tides in winter, being greatest.

If the tides are stronger after the full moon, it is because that luminary increases by her heat the polar effusions, and consequently the quantity of water in the ocean.

Let us now, continues M. St. Pierre, explain why the tides of the South sea do not resemble those of the Atlantic ocean. The irregular

effusions of the poles, not being narrowed in the southern hemisphere, as in ours, produce on the shores of the Indian ocean and South sea expansions vague and intermitting. The south pole has not, like the north pole, a double continent, which separates into two the divergent effusions daily produced by the sun: it has no channel in passing through which its effluxes should be retarded: its effusions accordingly flow directly into the vast southern ocean, forming on the half of that pole a series of divergent emanations which perform the tour of it in 24 hours, like the rays of the sun. When a bundle of these effusions falls upon an island, it produces there a tide of twelve hours, *i. e.* of the same duration with that which the sun employs in heating the icy cupola through which the meridian of that island passes; such are the tides of the islands of Otaheite, Massafuero, New Holland, New Britain, &c.: each of these tides lasts as long as the course of the sun above the horizon, and is regular like his course.

In the northern part of the South sea the two continents approach: they pour therefore by turns, in summer, into the channel which separates them, the two semi-diurnal effusions of their pole, and there they collect by turns, in winter, those of the south pole, which produces two tides a day as in the Atlantic ocean. But as this channel about the 55° of N. lat. ceases to exist by the sudden divergence of the continents of Asia and America, those places only situated in the point of divergence of the northern parts of these two continents experience two tides a day. Such are the Sandwich Islands. Where such places are more exposed to the current of the one continent than the other, its two semi-diurnal tides are unequal, as at the entrance of Nootka Sound: but when it is completely out of the influence of the one, and entirely under that of the other, it receives only one tide of twelve hours every day, as at Kamschatka. Thus, two harbours may be situated in the same sea under the same parallel, and one of them have two tides, and the duration of these tides, whether double or single, double equal or double unequal, regular or retarded, is always 12 hours every 24 hours, *i. e.* precisely the time the sun employs in heating that half of the polar cupola from whence they flow; which cannot possibly be referred to the unequal course of the sun between the tropics, and much less to that of the moon, which is

frequently but a few hours above the horizon of such harbours. All islands are in the midst of currents: on looking therefore at the south pole with a bird's eye view, we should see a succession of archipelagos dispersed in a spiral line all the way to the northern hemisphere, which indicates the current of the sea, just as the projection of the two continents on the side of the north pole indicates the current of the Atlantic. Thus, the course of the seas from one pole to the other is in a spiral line round the globe, like the course of the sun from one tropic to the other: admitting therefore the alternate fusion of the polar ices, all the phænomena of the tides and currents of the ocean may be explained with the greatest facility.

I have then established by facts simple, clear, and numerous, the disagreement of the tides in most seas with the moon's action on the equator, and their perfect coincidence with the sun's action on the polar ices.

I have no doubt various objections may be urged against this hasty explanation of the course of the tides, &c. But these physical causes present themselves with a higher degree of probability, simplicity, and conformity to the general progress of nature, than the astronomical causes by which it is attempted to explain them.

Thus far St. Pierre, who complains that the prejudices of mankind are so strong in favour of received opinions, that he cannot obtain a hearing.

To the best of my judgment I have offered a fair and candid exposition of a hypothesis which he has dressed up with some eloquence and much declamation, and ushered into the world with a solemn and imposing air of confidence and assurance, tolerably well calculated to confound the ignorance and candour of his readers. I am not conscious of having omitted any material fact or argument which tends to the support and elucidation of his theory; I have neglected much absurd reasoning, yet not without retaining some curious specimens. I did once intend to have entered into a general examination of his principles and reasoning; to have shown the fallacy of the former, the inconclusiveness and inconsistency of the latter; but I shall now be satisfied with offering a few facts and observations extracted from the second and third voyage of Captain Cook, which appear to me decisive of the question.

Captain Cook, who spent three summers as near as the ice would permit his approach towards the south pole, found, on December 14, 1772, and from that date to the beginning of January 1773, in latitude from 55° to 64° south, a vast compact body of ice which prevented his further progress. The thermometer varied from 30° to 35°. Being immersed 100 fathom deep for about 20 minutes, it came up 34°; and on the 13th of January 1774, on a repetition of this experiment, the open air being 36°, the surface of the sea 33½°, the thermometer came up 32°. They found water generally freeze at 33°. "We certainly had no thaw, (says he,) the mercury keeping usually below the freezing point. Being near an island of ice (December 24, 1772) 50 feet high and 400 fathom in circuit, I sent the master in the jolly boat to see if any water ran from it. He soon returned with an account there was not one drop, or any other appearances of thaw." And in the summer of 1774—75 his experience was nearly similar. On the 13th of February 1775, the thermometer stood at 29°. In his third voyage to the north-west coast of America, on the 17th of August 1778, in lat. 70° 44′, they were stopped by a field of ice 10 or 12 feet high, as compact as a wall; "further north it appeared much higher; here and there we saw upon it pools of water; we tried but found no current. July 7, 1779, lat. 69°; stopped by a large field of ice, presenting a great extent of solid and compact surface not in the smallest degree thawed: the thermometer stood at 31°."

"As far as our experience went, the sea is clearer of ice in August than in July, and perhaps it may be still freer in a part of September. We tried the currents, and found them never to exceed a mile an hour; we found the month of July infinitely colder than August; the thermometer in July was once 28°, and very commonly 30; whereas it was seldom as low as the freezing point in August."

"I am of opinion (says Captain Cook) that the sun contributes very little towards reducing these vast masses of ice; for, although that luminary is a considerable time above the horizon, it seldom shines out more than a few hours at a time, and often is not seen for several days in succession. It is the wind, or rather the waves raised by the wind, that reduces the bulk of these enormous masses, by grinding one piece against another, and by undermining and washing away those parts that lie exposed to the surge; and more

ice may be destroyed in one stormy season than is formed in several winters, and its accumulation thus prevented."

This evidence clearly proves that the sun's influence at the poles, so far from being equal to produce a constant and uniform effect, creating an impulse extending its effect to the remotest parts of our globe, and a daily elevation of several feet to the waters of the ocean, is not sufficient in the hottest period of summer to diffuse a sensible thaw; and thus we are convinced that a few plain and simple facts are of much greater avail than a multitude of fanciful conjectures.

[*Phil. Mag. Vol.* VIII.]

SECTION VII.

Currents, Gulph-streams, and Temperature of the Sea.

Besides the common and periodical tides described and explained in the preceding section, a variety of local currents are frequently met with in different seas, on different parts of the ocean, for the most part not far from land. These are usually and perhaps correctly ascribed to particular winds, but they do not always appear to issue from this cause, nor is it easy to ascertain their origin; occasionally indeed they have been traced below the surface of the water, running in a contrary direction to the stratum of water above, and in such cases undoubtedly the result of something very different from winds or monsoons. This last has often been ascribed, and at times, perhaps, correctly, to the immense masses of polar ice, producing a greater degree of cold in the under than in the upper water: whence Count Rumford suspects there is an under current of cold water flowing perpetually from the poles towards the equator, even where the superior water flows from the equator towards the poles; and he thus endeavours to account for the great inferiority of temperature which is frequently found in deep and superficial soundings of the same space of water.

The following ingenious article inserted in the Philosophical Transactions for 1684, by Dr. Smith, furnishes us with various instances of under-currents, and at the same time accounts for them upon a different principle.

" In the Offing, between the North and South Foreland, it runs tide and half tide, that is, it is either ebbing water or flood on the

shore, in that part of the Downs three hours, which is, grossly speaking, the time of half a tide, before it is so off at sea. The reason of this diversity of tides I take to be from the meeting of the two seas in that narrow strait. Often when the wind has blown hard at N. E. or at W. or W. and by S. there has happened an alteration of the tides in the Thames, which ignorant people have mistakingly reckoned a prodigy. And, it is a most certain observation, that where it flows tide and half tide, though the tide of flood runs aloft, yet the tide of ebb runs under foot, that is, close by the ground; and so at the tide of ebb, it will flow under foot.

" Now, as to the Straits, there is a vast draught of water poured continually out of the Atlantic into the Mediterranean; the mouth or entrance of which between Cape Spartel or Sprat, as the seamen call it, and Cape Trafalgar, may be near seven leagues wide, the current setting strong into it, and not losing its force till it runs as far as Malaga, which is about 20 leagues within the Straits. By the benefit of this current, though the wind be contrary, if it does not overblow, ships easily turn into the Gut, as they term the narrow passage, which is about 20 miles in length. At the end of which are two towns, Gibraltar on the coast of Spain, which gives denomination to the strait, and Ceuta on the Barbary coast; at which places Hercules is supposed to have set up his pillars. What becomes of this great quantity of water poured in this way, and of that which runs from the Euxine into the Bosphorus and Propontis, and carried at last through the Hellespont into the Ægean or Archipelago, is a curious speculation, and has exercised the ingenuity of philosophers and navigators. For there is no sensible rising of the water all along the Barbary coast, even down to Alexandria, the land beyond Tripoli, and that of Egypt lying very low, and easily to be overflowed. They observe, indeed, that the water rises three feet or three feet and ½ in the gulf of Venice, and as much, or very near as much, all along the river of Genoa, as far as the river Arno; but this rather adds to the wonder.

" I here omit to speak at large of the several hypotheses which have been invented to solve this difficulty; such as subterraneous vents, cavities, and indraughts, exhalations by the sun-beams, the running out of the water on the African side, as if there were a kind of circular motion of the water, and that it only flowed in upon the

Christian shore, which latter I consider as a mere fancy, and contrary to all observation.

"My conjecture is, that there is an under-current, by which as great a quantity of water is carried out as comes flowing in. To confirm which, besides what I have said above about the difference of tides in the offing, and at the shore in the Downs, which necessarily supposes an under-current, I shall present you with an instance of the like nature in the Baltic sound, as I received it from an able seaman, who was at the making of the trial. He told me, that being there in one of the king's frigates, they went with their pinnace into the mid stream, and were carried violently by the current; that soon after they sunk a bucket with a large cannon ball, to a certain depth of water, which gave check to the boat's motion, and sinking it still lower and lower, the boat was driven ahead to windward against the upper current: the current aloft, as he added, not being four or five fathom deep, and that the lower the bucket was let fall, they found the under current the stronger."

Of upper currents, Mr. Rennell has particularly described a very singular one often prevailing to the westward of Scilly, and dangerous to ships that approach the British Channel *. They are, however, more frequently met with about the Straits of Gibraltar, and near the Antilles. These latter are especially worthy of notice, and are thus described and accounted for by Dr. Peysennel †.

The coasts of these American islands are subject to counter-tides, or extraordinary currents, which render it very dangerous to chaloupes and other small craft to land; while at the same time the boats and ships in the roads are scarcely ever sensible of them, and seldom incommoded by them; nor do those who are out at sea appear to be affected by them. It is however certain that a regular wind constantly blows, in these parts of the torrid zone, from the tropic of Cancer, to the equinoctial line, from the east; inclining sometimes northward, and sometimes southward. This wind is called alizé, or trade-wind, for reasons admitted by philosophers, and it draws the water westward, giving a total and uniform course to that immense quantity, which comes from the great river of the Amazons, and from an infinite number of other rivers, which discharge themselves into the ocean. These currents passing

* Phil. Trans. 1793. Vol. lxxxiii. † Ib. 1755. Vol. xlix.

to the westward go up to the American islands, then to the coasts of Jucatan and Mexico, and running round in the gulf, return into the great ocean, by the straits of Bahama, along the coasts of Florida, in order to pursue, in the north, the course ordained them by the Supreme Being. It is in this course the waters are known to run with an extraordinary rapidity: they pass between the great and little islands of America, in the great deeps, by an almost even and imperceptible motion; but against the shores and coasts of these islands, which form this archipelago, these currents are very sensible and dangerous; they interrupt the navigation, insomuch that it is scarcely possible to stem these tides to get to the eastward.

It often happens, that vessels steering from St. Domingo, or the other Leeward islands, to the windward ones, cannot absolutely accomplish it, and are therefore obliged to get out of the channel, and steer away to the northward, in order to tack up to the windward isles. These are daily observations, and well known to all navigators of America.

Besides these regular currents, there are others, called countertides, which are observable on the sea-coasts and shores. In places where these flow, the sea rises in an extraordinary manner, becoming very furious without any apparent cause, and without being moved by any wind; the waves rise and open very high, and break against the shore, with such violence, that it is impossible for vessels to land. These he thinks are chiefly caused by the pressure of heavy black clouds sometimes seen hanging over an island or the sea. As to other currents in the main seas, or in other particular situations, as the gut and the coasts of the Mediterranean, Dr. Peysennel ascribes them to the action of the winds, &c.

The most extraordinary current we are acquainted with is that of the gulf of Florida, incidentally glanced at above. It is thus described by Sir Charles Blagden *.

One of the most remarkable facts observed in navigating the ocean, is that constant and rapid current which sets along the coast of North America to the northward and eastward, and is commonly known to seamen by the name of the gulf-stream. It seems justly attributed to the effect of the trade-winds, which, blowing from the

* Ib. 1781, vol. lxxi.

eastern quarter into the great Gulf of Mexico, cause there an accumulation above the common level of the sea; in consequence of which, it is constantly running out by the channel where it finds least resistance, that is, through the Gulf of Florida, with such force as to continue a distinct stream to a very great distance. Since all ships going from Europe to any of the southern provinces of North America must cross this current, and are materially affected by it in their course, every circumstance of its motion becomes an object highly interesting to the seaman, as well as of great curiosity to the philosopher.

During a voyage to America in the spring of the year 1776, Sir Charles used frequently to examine the heat of sea-water newly drawn, in order to compare it with that of the air. The passage was made far to the southward. In this situation, the greatest heat of the water which he observed was such as raised the quicksilver in Fahrenheit's thermometer to $77\frac{1}{2}$. This happened twice; the first time on the 10th of April, in latitude 21° 10′ N. and longitude by reckoning 52° W.; and the 2d time 3 days afterwards, in latitude 22° 7′ and longitude 55°; but in general the heat of the sea near the tropic of Cancer about the middle of April was from 76° to 77°.

The rendezvous appointed for the fleet being off Cape Fear, their course, on approaching the American coast, became north westward. On the 23d of April the heat of the sea was 74°, the latitude at noon 28° 7′ N. Next day the heat was only 71°, then in latitude 29° 12′; the heat of the water, therefore, was now lessening very fast in proportion to the change of latitude. The 25th the latitude was 31° 3′; but though they had thus gone almost 2° farther to the northward, the heat of the sea was this day rather increased, it being 72° in the morning, and $72°\frac{1}{2}$ in the evening. Next day, the 26th of April, at half after 8 in the morning, the thermometer rose to 78°; higher than he had ever observed it, even within the tropic. As the difference was too great to be imputed to any accidental variation, Sir C. Blagden immediately conceived that they must have come into the gulf-stream, the water of which still retained great part of the heat that it had acquired in the torrid zone. This idea was confirmed by the subsequent regular and quick diminution of the heat: the ship's run for a quarter of an hour had les-

sened it 2°; the thermometer at $8\frac{3}{4}^{h}$ being raised by sea-water fresh drawn only to 76°; by 9 the heat was reduced to 73°, and in $\frac{1}{4}$ of an hour more, to 71° nearly: all this time the wind blew fresh, and they were going 7 knots an hour on a north-western course. The water now began to lose the fine transparent blue colour of the ocean, and to assume something of a greenish olive tinge, a well-known indication of soundings. Accordingly, between 4 and 5 in the afternoon ground was struck with the lead at the depth of 80 fathoms, the heat of the sea being then reduced to 69°. In the course of the following night and next day, as they came into shallower water and nearer the land, the temperature of the sea gradually sunk to 65°, which was nearly that of the air at the time.

Bad weather on the 26th prevented them from taking an observation of the sun; but on the 27th, though it was then cloudy at noon, they calculated the latitude from 2 altitudes, and found it to be 33° 26′ N. The difference of this latitude from that which was observed on the 25th, being 2° 23′, was so much greater than could be deduced from the ship's run marked in the log-book, as to convince the seamen that they had been set many miles to the northward by the current.

From these observations, the writer thinks it may be concluded, that the gulf-stream, about the 33d degree of north latitude, and the 76th degree of longitude west of Greenwich, is, in the month of April, at least 6 degrees hotter than the water of the sea through which it runs. As the heat of the sea-water evidently began to increase in the evening of the 25th, and as the observations show that they were getting out of the current when he first tried the heat in the morning of the 26th, it is most probable that the ship's run during the night is nearly the breadth of the stream measured obliquely across; that, as it blew a fresh breeze, could not be much less than 25 leagues in 15 hours, the distance of time between the two observations of the heat, and hence the breadth of the stream may be estimated at 20 leagues. The breadth of the Gulf of Florida, which evidently bounds the stream at its origin, appears by the charts to be 2 or 3 miles less than this, excluding the rocks and sand-banks which surround the Bahama Islands, and the shallow water that extends to a considerable distance from the coast of Florida; and the correspondence of these measures is very remark-

able, since the stream, from well known principles of hydraulics, must gradually become wider as it gets to a greater distance from the channel by which it issues.

We have observed, that where there is an under current, it has in many cases been found colder than the upper; or rather that an under current has often been conjectured to exist, from this circumstance. Thus on long. 31, in lat. 69, when the temperature of the atmosphere, and of the surface of the sea, was 59½ Fahren. Lord Mulgrave found that the water at the depth of 4038 feet, sunk the thermometer to 32°. And at the tropic, where the difference of seasons never produces a difference of more than five or six degrees, the variation between the heat of the water at the surface of the sea, and that at the depth of 3600 feet, has been found to amount to not less than 31°, the superior temperature measuring 84°, and that below not more than 43°.

It is a curious fact, however, that in the northern seas, where we should expect this difference to take place with the greatest precision, it exhibits the greatest uncertainty, the lower water being sometimes warmer and sometimes colder. In proof of this we insert the following result of the trials made by Charles Douglas, Esq. of his Majesty's ship the Emerald, in the year 1769, off the coasts of Norway and Lapland, as thrown into a tabular form by Dr. Thomson.

Date.	Latitude.	Temperature.			Depth.
		Open air.	Surface of sea.	Bottom.	
May 12	70° 40′	27°	36°	39°	87 fathoms.
17	Ditto.	38	37	39	90
22	70° 32′	40	37	39	80
June 29	70° 54′	47	44	40	98
July 7	70 45	46	46	44	70
8	68 43	46	47	52	260
8	68 43	46	47	46	100
9	65 25	48	48	48	210
9	65 25	48	48	46	100
10	64 40	52	52	46	141
10	64 40	52	52	45	75

The experiments were made by letting down the thermometer enclosed in a tin cylinder filled with water, and letting it remain at

the bottom for half an hour. It was sunk by means of the deep sea-sounding lead *.

[EDITOR.

SECTION VIII.

On the Motion of Waves, and the Effects of Oil in quieting them.

IT will easily be conceived that the waves rise higher or lower, according to the power of the original moving force; for the more water is displaced by that force, the greater quantity of it must be elevated above the usual level; and of course the breadth of the waves is likewise greater.

It seems to be pretty well determined from a variety of experiments and observations, that the utmost force of the wind cannot penetrate a great way into the water; and that in great storms the water of the sea is slightly agitated at the depth of 20 feet below the usual level, and probably not moved at all at the depth of 30 feet or five fathoms †. Therefore the actual displacing of the water by the wind cannot be supposed to reach nearly so low; hence it should seem that the greatest waves could not be so very high as they are often represented by accurate and creditable navigators. But it must be observed that in storms, waves increase to an enormous size from the accumulation of waves upon waves; for as the wind is continually blowing, its action will raise a wave upon another wave, and a third wave upon a second, in the same manner as it raises a wave upon the flat surface of the water. In fact, at sea, a variety of waves of different sizes are frequently seen one upon the other, especially whilst the wind is actually blowing. And when it blows fresh, the waves, not moving sufficiently quick, their tops, which are thinner and lighter, are impelled forward, are broken, and turned into a white foam, particles of which, called the *spray*, are carried a vast way.

Waves are circular, or straight, or otherwise bent, according as the original impression is made in a narrow space nearly circular, or in a straight line, or in other configurations. In open seas the waves

* Phil. Trans. 1770. Vol. lx. p. 39.

† Boyle's works, folio edition, vol. iii. Relations about the bottom of the sea; sect. iii.

generally are in the shape of straight furrows, because the wind blows upon the water in a parallel manner, at least for a long apparent tract.

When the water receives several impulses at the same time, but in different places, then the waves which proceed from those places must necessarily cross each other.—By this crossing the waves do not disturb each other; but they follow their proper directions, by passing one upon the other. Thus if two stones be thrown upon the surface of stagnant water nearly at the same time, but at a little distance from each other; the circular waves which proceed from those places will be clearly perceived to cross each other, and to follow their peculiar courses. The reason of which is, that the same cause which produces the alternate rising and falling of the water upon the surface of otherwise stagnant water, must operate in the same manner, and must produce the like effect on the surface of another wave.

When a wave meets with an obstacle which is straight and perpendicular, such as a wall, or a steep bank, then the wave is reflected by it, and the shape of the reflected or retrogade wave, i s the reverse of what it would have been on the other side of the obstacle, had the obstacle not existed: For the middle part of the curvature must naturally meet the obstacle, and must be reflected by it first. And since waves will cross without obstructing each other, the reflected waves will proceed from the obstacle, and will expand all round, &c.

When the bank or obstacle is inclined to the horizon, as is frequently the case on the shores of the sea; then the reflection of the waves is disturbed, and it is often absolutely destroyed by the friction of the water upon the ground.

If the obstacle be such as to reflect a part only of the wave, such as a stone or a post, which is surrounded by the water; then the wave will be partly reflected in shapes and directions which differ according to the form and size of the obstacle, whilst the rest of the wave will proceed in its original direction.

When a hole in an obstacle permits part only of a wave to go through, then circular waves will be formed on the other side of the obstacle, whose centre is the hole; for in fact those waves owe their origin to the motion of the water in that place only.

The same causes which raise water into waves, must evidently produce the like effect on other fluids, but in different degrees, according as the fluid is more or less heavy, as its particles adhere more or less forcibly to each other, and probably likewise according as there is a greater or less degree of attraction between the fluid and the other body, which gives it the impulse.

When a stone or other heavy body is dropped on the surface of oil, the waves are not nearly so high, nor so quick, neither do they spread so far as the waves of water. This effect is evidently owing to the clamminess, or great degree of adhesion between the particles of the oil.

If the waves upon oil be attempted to be raised by the force of wind, it will be found very difficult to succeed even in a moderate degree. This difficulty is, in a great measure, owing to the attraction between the particles of oil; but besides this, there may be less attraction between oil and air, than between the latter and water; for water always contains a certain quantity of air; and if it be deprived of that air by means of boiling or otherwise, a short exposure to the atmosphere will enable the water to reimbibe it.

It is likewise probable, that the surface of water, even when stagnant, may not be so smooth as the surface of oil; so that the wind may more easily catch into the inequalities of the former than of the latter.

It is remarkable that the effect of the wind upon water may, in a great measure, be prevented or moderated, by spreading a thin film of oil on the surface of the water.

No great quantity of oil is required for this purpose; for, though oil be very clammy and adhesive to almost all other bodies; yet when dropped upon water, it will instantly spread and extend itself over a vast surface of water; and it will even drive small floating bodies out of its way, acquiring, as it seems, a repulsive property amongst its own particles.

This repulsion may be shewn in the following amusing manner: Cut a light shaving of wood, or of paper, in the form of a comma, smear it with oil, then place it upon the surface of a pretty large piece of smooth water; and the bit of wood or paper will be seen to turn round in a direction contrary to that of the point, which is occasioned by the stream of oily particles issuing from the point, and

spreading themselves over the surface of the water. This experiment will not succeed in a bason or other small vessel full of water, wherein the particles of oil have not room enough to expand themselves.

If a heavy body be dropped on the surface of water which is thus covered with a film of oil, the waves will take place in the same manner as if there were no oil. But the blowing of the wind will have little or no effect upon it. In this case the oil seems to act between water and air, in the same manner as it acts between the moving parts of mechanical engines; viz. it lubricates the parts, and renders the motion free and easy.

But whether this be the real explanation or not, the fact is not less true than surprising; and a very useful consequence has been derived from it, namely, a method of stilling the waves of the sea in certain cases.

It is expressly mentioned by Plutarch * and Pliny †, that the seamen of their times used to still the waves in a storm, by pouring oil into the sea. But since the revival of learning, though several observations relative to it are to be found in accounts of voyages, &c. yet I do not know that any notice has been taken of this account by any philosophical writer, previous to the late celebrated Dr. Franklin, who collected several accounts relative to the subject, and made a variety of experiments upon it, the sum of which is as follows ‡.

A small quantity of oil, for instance, a quarter of an ounce, will spread itself quickly and forcibly upon the water of a pond or lake, to the extent of more than an acre; and if poured on the windward side, the water will thereby be rendered quite smooth as far as the film of oil extends, whilst the rest of the pond may be quite rough, from the action of the wind.

If the oil be poured on the leeward side, then the force of the wind will, in a great measure, drive it towards the bank. Besides which, the experiment is frustrated by the waves coming to that side already formed; for the principal operation of the oil upon water is, as it seems, 1st. to prevent the raising of new waves by the wind;

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* Quæst. Nat. † Hist. Nat. lib. ii. c. 103.

‡ See his paper on the stilling of waves by means of oil, in the Phil. Tran. vol. lxiv. or in his Miscellaneous Papers.

and 2dly. to prevent its driving those which are already raised with so much force, as it would if their surface were not oiled.

Such experiments at sea are evidently attended with a great many difficulties; but in particular cases essential advantages may be derived from the use of oil, and several instances of its having been of very great service, are recorded *. "We might," says Dr. Franklin, "totally suppress the waves in any required place, if we could come at the windward place, where they take their rise. This in the ocean can seldom, if ever, be done. But, perhaps, something may be done on particular occasions, to moderate the violence of the waves, when we are in the midst of them, and prevent their breaking, where that would be inconvenient.

"For when the wind blows fresh, there are continually rising on the back of every great wave, a number of small ones, which roughen its surface, and give the wind hold, as it were, to push it with greater force. This hold is diminished by preventing the generation of those small ones. And possibly too, when a wave's surface is oiled, the wind, in passing over it, may rather in some degree press it down, and contribute to prevent its rising again, instead of promoting it."

Light, volatile, or etherial oils, like ether, spirit of turpentine, &c. do not possess the same property as fat oils, such as olive oil, linseed, rape-seed oil, train oil, &c.

[*Cavallo. Nat. Hist.*

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* Mr. Tengnagel, in a letter to Count Bentinck, dated Batavia, January the 5th, 1770, says, "Near the Islands Paul and Amsterdam, we met with a storm which had nothing particular in it worthy of being communicated to you, except that the Captain found himself obliged, for greater safety in wearing the ship, to pour oil into the sea, to prevent the waves breaking over her, which had an excellent effect, and succeeded in preserving us." Phil. Tran. vol. lxiv. p. 456.

It has been remarked in Rhode Island, that the harbour of Newport is ever smooth whilst any whaling vessels are in it; which is, in all probability, owing to the fish-oil that may come out of them.

It is said to be a practice with the fishermen of Lisbon, when about to return into the river (if they see before them too great a surf upon the bar, which they apprehend might fill their boats in passing) to empty a bottle or two of oil into the sea, which will suppress the breakers, and allow them to pass safely.

In various parts of the coast of the Mediterranean, and elsewhere, it is a practice of the fishermen, to sprinkle a little oil upon the water, which smooths the surface of the water that is ruffled by the wind, and thus enables them to see and to strike the fish.

SECTION IX.

On the force of the Rudder, and the manner in which it acts.

THE force by which the rudder of a ship makes her move in any direction, at pleasure, excites no small degree of astonishment; especially when we consider the weak action of the enormous rudders with which some of the barges that navigate our rivers and canals are furnished. The cause of this phenomenon we shall here endeavour to explain and illustrate.

The rudder of a barge or vessel has no action unless impelled by the water. It is the force resulting from this impulse, which being applied in a direction transversal to the poop, tends to make the vessel turn around a point of its mass, called the spontaneous centre of rotation. The prow of the vessel describes around this point an arc of a circle, in a direction opposite to that described by the poop; hence it follows that the prow of the vessel turns towards that side to which the rudder is turned, consequently opposite to that side towards which the tiller or lever of the rudder is moved. Hence, when the tiller is moved to the starboard side, the vessel turns towards the larboard, and *vice versa.*

A force, and even a certain degree of intensity, must therefore be applied to the rudder to make the vessel turn; and on this account the construction of the vessel is so contrived, as to increase this force as much as possible; for while the barges which navigate our rivers are in general very broad behind, and screen as we may say the rudder, so that the water flowing along their sides can scarcely touch it, the stern of vessels intended for sea are made narrow and slender, so that the water flowing along their sides must necessarily strike against the rudder, if in the least moved from the direction of the keel. Let us therefore endeavour to estimate nearly the force which results from this impulse.

A vessel of 900 tons, when fully laden, draws 13 or 14 feet of water, and its rudder is about two feet in breadth. Let us now suppose that the vessel moves with the velocity of two leagues per hour, which makes 176 yards per minute, or about nine feet per second; if the rudder be turned in such a manner as to make with the keel a continued angle of 30 degrees, the water flowing along

the sides of the vessel will impel the rudder under the same angle, that is 30 degrees. The part of the rudder under water being 14 feet in length and two in breadth, presents a surface of 28 square feet, impelled at an angle of 30 degrees, by a body of water flowing with the velocity of nine feet per second. But the action of such a current, if it impelled a similar surface in a perpendicular direction, would be 2205 pounds, which must be reduced in the ratio of the square of the sine of incidence to that of radius, or in the ratio $\frac{1}{4}$ to one, since the sine of 30 degrees is $\frac{1}{2}$, radius being one. The effort therefore of the water will be 551 pounds. Such is the force exercised perpendicularly on the rudder; and to find the quantity of this force that acts in a direction perpendicular to the keel, and which makes the vessel turn, nothing is necessary but to multiply the preceding effort by the cosine of the angle of inclination of the rudder to the keel, which in this case is $\sqrt{\frac{3}{4}}$ or 0·866, which will give 477 pounds.

The above computation is made on the old supposition, that the force of the water is diminished in proportion as the square of the sine of the incident angle is less than the square of the radius. But, by more accurate experiments it is found (Dr. Hutton's Math. and Philos. Dictionary, Tab. 3, Resistance), that at an angle of 30 degrees, the absolute force is diminished only in the ratio of 840 to 278; hence then, the whole force 2205 pounds, reduced in this ratio, comes out 730 pounds, for the effective or perpendicular force on the rudder, to turn it or indeed the ship about, supposing the rudder held or fixed firm in that position.

But there is one cause which renders this effort more considerable: the water which flows along the sides of the vessel does not move in a direction parallel to the keel, but nearly parallel to the sides themselves, which terminate in a sort of angle at the stern-post, or piece of timber which supports the hinges of the rudder; so that this water bears more directly on the rudder by an angle of about 30 degrees: hence, in the above case, the angle under which the water impels the rudder will be nearly 60 degrees: we must therefore make this proportion, as the square of radius is to the square of the sine of 60 degrees, or as one is to $\frac{3}{4}$; so is 2205 to 1653. The force therefore which acts in a direction perpendicular to the keel, is 1653 pounds. Or, by the table in the Dictionary

above quoted, as 840 is to 729 (for 60°), so is 2205 to 1913 pounds, the perpendicular force.

This effort will no doubt appear very inconsiderable when compared with the effect it produces, which is to turn a mass of 900 tons; but it must be observed that this effort is applied at a very great distance from the point of rotation and from the vessel's centre of gravity; for this centre is a little beyond the middle of the vessel towards the prow, as the anterior part swells out, while the posterior tapers towards the lower works in order that the action of the rudder may not be interrupted. On the other hand, it can be shewn that what is called the spontaneous centre of rotation, the point round which the vessel turns, is also a little beyond the middle and towards the prow; hence it follows, that the effort applied at the extremity of the keel, towards the stern, acts to move the vessel's centre of gravity, by an arm of a lever 12 or 15 times as long as that by which this centre of gravity, where the weight of the vessel is supposed to be united, exerts its action. And lastly, there is no comparison between the action exercised by this weight when floating in water, and that which it would exert if it were required to raise it only one line. It needs therefore excite no surprise, that the weight of one ton, applied with this advantage, should make the vessel's centre of gravity revolve around its centre of rotation.

If the ship, instead of going at the rate of two leagues per hour sails at the rate of three, the force applied to the rudder will be to that applied in the former case, in the ratio of nine to four; consequently, if the position of the rudder be as above supposed, the actual force will be 3719 pounds, or rather 4304 pounds: if the velocity of the vessel were four leagues per hour, this force, in the same position of the rudder, would be four times as much as at first, or 6612 pounds, or rather 7652 pounds.

Hence it is evident why a vessel, when moving with rapidity, is more sensible to the action of the helm; for when the velocity is double, the action is quadrupled; this action then follows the square or duplicate ratio of the velocity.

If the water moves in a direction parallel to the keel when it impels the rudder, it will be found that this angle ought to be 54 degrees 44 minutes; but, as already observed, the water is carried along in an angular manner towards the direction of the keel con-

tinued; which renders the problem more difficult. If we suppose this angle to be 15 degrees, which Bouguer considers as near the truth, it will be found that the angle in question ought to be 46 degrees 40 minutes.

Ships do not receive the whole benefit of this force; for the length of the tiller does not permit the helm to form with the keel an angle of more than 30 degrees.

[*Hutton. Montucla's Ozanam.*]

SECTION X.

On the Velocity of a Vessel compared with that of the Wind.

A VESSEL can never acquire a velocity greater than, or even equal to, that of the wind, when in a direct course, or when she is sailing before the wind; for besides that in this case a part of the sails injure or intercept the rest, it is evident that if the vessel should by any means acquire a velocity equal to that of the wind, it would no longer receive from it any impulse; its velocity then would begin to slacken in consequence of the resistance of the water, until the wind should make an impression on the sails equal to that resistance, and then the vessel would continue to move in an uniform manner, without any acceleration, with a velocity less than that of the wind.

But, when the course of the vessel is in a direction oblique to that of the wind, this is not the case. Whatever may be its velocity, the sail is then continually receiving an impulse from the wind, which still approaches more to equality, as the course approaches a direction perpendicular to that of the wind: therefore, however fast the vessel advances, it may continually receive from the wind a new impulse to motion, capable of increasing its velocity to a degree superior to that even of the wind itself.

But for this purpose it is necessary that the construction of the vessel should be of such a nature, that, with the same quantity of sail, it can assume a velocity equal to 8-11ths or 3-4ths that of the wind. This is not impossible, if all the canvas which a vessel can spread to the wind, in an oblique course, were exposed in one sail in a direct course. This then being supposed, Bouguer shews, that if the sails be set in such a manner, as to make with the keel an angle of about fifteen degrees, and if they receive the wind in a per-

pendicular direction, the vessel will continually acquire a new acceleration, in the direction of the keel, until her velocity be superior to that of the wind, and that in the ratio of about four to three.

It is indeed true, that, as the masts of vessels are placed at present, it is not possible that the yards can form with the keel an angle less than forty degrees; but some navigators assert, that by means of a small change this angle might be reduced to thirty degrees. In this case, and supposing that the vessel could acquire in the direct line a velocity equal to 3-4ths that of the wind, the velocity which it would acquire by receiving the wind on the sails at right angles, might extend to 1·034 that of the wind, which is a little more than unity, and therefore somewhat more than the velocity of the wind.

If we suppose the same velocity possible in the direct course, and that the sail forms with the keel an angle of 40 degrees, it will be found that the velocity acquired by the vessel, in an oblique course, will be nearly 19-20ths the velocity of the wind.

This at least will be the case, if in this position of the sails, in regard to the wind, they do not hurt or obstruct each other. If all these circumstances therefore be combined, it appears that though it is possible, speaking mathematically, that a vessel can move with the same velocity as the wind, or even with a greater, it will be very difficult to produce this effect in practice.

[*Hutton. Montucla's Ozanam.*]

SECTION XI.

On sweetening Sea-water.

As a knowledge of the means whereby fresh or sweet water may be procured from salt water is of the utmost importance to seafaring men, we shall here offer a few remarks on this subject.

Sweet water may be obtained from salt water by two methods, by freezing such water, or by distilling it.

When sea-water is exposed to a degree of cold somewhat below the point at which fresh water freezes, its power of holding muriate of soda and other saline substances in solution, is in part destroyed; ice is formed on the upper surface, while the fluid portion underneath becomes a concentrated brine. This ice when melted yields

a water, which contains so little saline matter as scarcely to be distinguished from fresh water by the taste, or indeed by chemical tests. It is evident, however, that this method can only be resorted to in certain latitudes or at certain seasons of the year.

The other method, therefore, viz. that of distillation, is greatly to be preferred, being feasible (with a proper apparatus) at all times and in all situations, and, when properly conducted, yielding a water as pure and as sweet as that procured by congelation. It was formerly supposed that in order to obtain fresh water from sea-water it was necessary to add to this last, before the distillation, calcareous earth, potash, or certain other substances, for the purpose of absorbing and retaining a bituminous matter, which all sea-water was supposed to contain in greater or less quantity, and to which was ascribed the unpleasant empyreumatic taste of the water distilled from it, especially if too strong a fire is employed, or the distillation is pushed too far. Dr. James Lind, however, has proved that such additions are useless, since pure rain water contracts in like manner a burnt taste by distillation; which shows that it is derived from the action of the elementary water on the heated metallic vessels. This disagreeable flavour, however, goes off, for the most part, on exposing the distilled water to the air. Nothing more is requisite, then, for obtaining fresh water from salt water, than to be provided with a common still; or with still-head covers made to fit the coppers used for boiling provisions on board of ship; and a worm-tub or cooler for condensing the steam. (See Dr. Lind's Essay on preserving the health of Seamen. Also, the Appendix to his Essay on Diseases incidental to Europeans in Hot Climates.) Some years after this discovery was made known by Dr. Lind, [It would appear however that the simple distillation of sea-water, for the purpose of procuring fresh water, was practised by Sir Richard Hawkins, in the reign of Queen Elizabeth. See the Bishop of Llandaff's (Dr. Watson's) Chemical Essays, vol. ii.] an improvement was suggested by Dr. Irving, in the mode of distillation; wherein he substituted for the condensation of the steam, a large open pipe kept constantly wet with mops, in place of the small slender pipe passed through a tub of cold water, in the usual way. This, from being applied to larger coppers than the common method ever had been in the distillation of sea-water, yielded in a given time, and with the same quantity of fuel, a larger quantity of fresh water.

Whether the distillation be made after Dr. Lind's method, or with the more simple contrivance of Dr. Irving, the operator should be careful not to continue the process too long, but to stop when three-fourths or only two-thirds of the water shall have been distilled; as the water which is obtained afterwards is less pure, and the brine sometimes becomes so strong as to corrode the copper boiler. [It appears from the Bishop of Llandaff's experiments (see his Chemical Essays before quoted) that the water distilled from salt-water is not wholly free from saline particles; but that it probably contains them in so small a proportion as not to injure its salubrity in any sensible degree.] When too much fire is employed it is possible, especially towards the end of the operation, that some muriatic acid may be disengaged, the action of which upon the metallic vessels it must be desirable to prevent. This might perhaps be effected by adding some potash to the sea-water.

[*Phil. Trans. Abr. Vol.* I. *p.* 549, *Note of the Editors.*]

This subject is so important that it has occupied the attention of the chemists of the continent as well as of our own country for these fifty years past. It was at first conceived not only as above stated, that sea-water abounds with bituminous matter, but with ammoniacal gas from the decomposition of animal bodies of all kinds; and hence, in the process of distilling, means were taken to divest the sea-water of this substance, as well as of its supposed bitumen. Admitting the fact, for which, however, there is no authority, the distilled water, when the process is carefully conducted, as above, will be as free from ammonia as from bitumen.

One of the earliest writers upon the subject is Mr. Hanton, whose refrigeratory is worthy of notice on account of its simplicity: for, in order to save the space of a large vessel, in which the worm is generally placed, and the trouble of filling it with cold water, he made it pass through one aperture in the side of the ship into the sea, and return by another, so that the sea itself performed the office of a refrigeratory.

Captain Wm. Chapman, under a great want of water in peculiar circumstances, exhibited an ingenuity, though under the old system, that is well worthy of notice. Sometime in September 1757, after his crew had been ten days at sea, by an accident (off the north cape of Finland) they lost the greatest part of their water. They

had a hard gale of wind at S. W. which continued three weeks, and drove them into 73° lat. During this time he was very uneasy, as knowing if their passage should hold out long, they must be reduced to great straits; for they had no rains, but frequent fogs, which yielded water in very small quantities. He now blamed himself for not having a still along with him, as he had often thought no ship should be without one. But it was now too late; and there was a necessity to contrive some means for their preservation.

He was not a stranger to Appleby's method: he had also a pamphlet written by Dr. Butler, intitled, An easy Method of procuring Fresh Water at Sea. And he imagined, that soap might supply the place of capital lees, mentioned by him. He now set himself at work to contrive a still; and ordered an old pitch-pot, that held about ten quarts, to be made clean: the carpenter, by his direction, fitted to it a cover of fir-deal, about two inches thick, very close; so that it was easily made tight by luting it with paste. They had a hole through the cover, in which was fixed a wooden pipe nearly perpendicular. This he should call the still-head; it was bored with an augre of 1½ inch diameter, to within 3 inches of the top or extremity, where it was left solid. They made a hole in this, towards the upper part of its cavity, with a proper angle, to receive a long wooden pipe, which they fixed in it, to descend to the tub in which the worm should be placed. Here again he was at a loss, for they had no lead pipe, nor any sheet lead, on-board. He thought, if he could contrive a straight pipe to go through a large cask of cold water, it might answer the end of a worm. They then cut a pewter dish, and made a pipe 2 feet long: and at 3 or 4 trials, for they did not let a little discourage them, they made it quite tight. They bored a hole through a cask, with a proper descent, in which they fixed the pewter pipe, and made both holes in the cask tight, and filled it with sea-water: the pipe stuck without the cask 3 inches on each side. Having now got his apparatus in readiness, he put 7 quarts of sea-water, and 1 oz. of soap into the pot, and set it on the fire. The cover was kept from rising by a prop of wood to the bow. They fixed on the head, and into it the long wooden pipe abovementioned, which was wide enough to receive the end of the pewter one into its cavity. They easily made the joint tight.

It need not be mentioned with what anxiety he waited for success: but he was soon relieved; for, as soon as the pot boiled, the water began to run; and in 28 minutes he got a quart of fresh water. He tried it with an hydrometer he had on board, and found it as light as river-water; but it had a rank oily taste, which he magined was given it by the soap. This taste diminished considerably in 2 or 3 days, but not so much as to make it quite palatable. Their sheep and fowls drank this water very greedily without any ill effects. They constantly kept their still at work, and got a gallon of water every 2 hours, which, if there had been a necessity to drink it, would have been sufficient for the ship's crew.

He now thought of trying to get water more palatable; and often perused the pamphlet abovementioned, especially the quotation from Sir R. Hawkins's voyage, who "with 4 billets distilled a hogshead of water wholesome and nourishing." He concluded he had delivered this account under a veil, lest his method should be discovered: for it is plain, that by 4 billets he could not mean the fuel, as they would scarcely warm a hogshead of water. When, ruminating on this, it came into his head, that he burnt his 4 billets to ashes, and with the mixture of those ashes with sea-water he distilled a hogshead of fresh water wholesome and nourishing. Pleased with this discovery, he cut a billet small, and burnt it to ashes: and after cleaning the pot, he put into it a spoonful of those ashes, with the usual quantity of sea-water. The result answered his expectations: the water came off bright and transparent, with an agreeable pungent taste, which at first he thought was occasioned by the ashes, but afterwards he was convinced it received it from the resin or turpentine in the pot, or pipes annexed to it. He was now relieved from his fears of being distressed through want of water; yet thought it necessary to advise his people not to be too free in the use of this, while they had any of their old stock remaining; and told them, he would make the experiment first himself; which he did, by drinking a few glasses every day without any ill effect whatever. This water was equally light with the other, and lathered very well with soap. They had expended their old stock of water before they reached England; but had reserved a good quantity of that which they distilled. After his arrival at Shields, he invited several of his acquaintance on board to taste the water;

they drank several glasses, and thought it nothing inferior to spring water. He made them a bowl of punch of it, which was highly commended.

He had not the convenience of a still, or he should have repeated the experiment for the conviction of some of his friends: for as to himself, he was firmly persuaded, that wood ashes mixed with sea-water would yield, when distilled, as good fresh water as could be wished for. And he thought, if every ship bound a long voyage was to take a small still with Dr. Hales's improvements, they need never want fresh water. Wood-ashes might easily be made, while there was any wood in the ship, and the extraordinary expense of fuel would be trifling, if they contrived so that the still should stand on the fire along with the ship's boiler.

All sweet or pure water, if preserved in wood, will soon dissolve a part of its interior surface, and become corrupt. To avoid this Mr. Bentham proposed the following plan, for which he received a gold medal from the Society of Arts. "The mode," says he, "in which I conceived fresh water might be preserved sweet, was merely by keeping it in vessels of which the interior lining at least should be of such a substance as should not be acted upon by the water, so as to become a cause of contamination. Accordingly, on-board two ships, the greater part of the water was kept, not in casks but in cases or tanks, which, though they were made of wood, on account of strength, were lined with metallic plates, of the kind manufactured by Mr. Charles Wyatt, of Bridge-street, under the denomination of tinned copper-sheets; and the junctures of the plates or sheets were soldered together, so that the tightness of the cases depended entirely on the lining, the water having no where access to the wood. The shape of these cases was adapted to that of the hold of the ship, some of them being made to fit close under the platform, by which means the quantity of water stowed was considerably greater than could have been stowed, in the same space, by means of casks; and thereby the stowage-room on-board ship, was very much increased.

The quantity of water kept in this manner on-board each ship, was about forty tons divided into sixteen tanks; and there was likewise, on-board each of the ships, about thirty tons stowed in casks as usual.

As the stowing the water in tanks was considered as an experiment, the water in the casks was used in preference; that in the tanks being reserved for occasions of necessity, excepting that a small quantity of it was used occasionally for the purpose of ascertaining its purity, or when the water in the casks was deemed, when compared with that in tanks, too bad for use.

The water in thirteen of the tanks, on-board one ship, and in all the tanks on-board the other, was always as sweet as when first taken from the source; but in the other three of the tanks, on-board one ship, the water was found to be more or less tainted as in the casks. This difference, however, is easily accounted for, by supposing that the water of these tanks was contaminated before it was put into them; for in fact the whole of the water was brought on-board in casks, for the purpose of filling the tanks, and no particular care was taken, to taste the water at the time of taking it on board

After the water kept in this manner had remained on-board a length of time which was deemed sufficient for experiment, it was used out, and the tanks were replenished as occasion required: but in some of the tanks, on-board one ship at least, the original water had remained three years and a half. About twenty-five gallons of the water, which had remained this length of time in the ship, were sent to the Society, in two vessels made of the same sort of tinned copper with which the tanks were lined.

A certificate from Captain William Bolton, commander of the said vessel, dated Sheerness, 28th of June, 1800, accompanied this letter, stating that the water delivered to the Society was taken from a tank holding about seven hundred gallons, and which his predecessor, Captain Portlock, had informed him had been poured into the tank in December 1796, except about thirty gallons added in 1798, and had remained good during the whole time.

In a letter, dated January 7, General Bentham also states, that the water which had been preserved sweet on-board his Majesty's sloops Arrow and Dart, was taken from the well at the king's brew-house, at Weevil, from whence ships of war, lying at or near Portsmouth, are usually supplied with water for their sea-store, as well as for present use."

EDITOR.

SECTION XII.

On Embankments, Piers, Harbours, and gaining Land from the Sea.

In various sections of the present chapter, and particularly that on *Inundations*, we have seen the dry land occasionally encroached upon to a very considerable extent by the natural action of different seas or rivers. In other instances, and particularly in the section of a preceding chapter, which treats of the formation of new islands, we have seen the dry land make similar encroachments upon the surrounding beds of water. "In this manner the boundaries of organized life are alternately extending and diminishing; in the former instance sometimes thrown up all of a sudden by the dread agency of volcanoes, and sometimes reared imperceptibly by the busy agency of corals and madrepores. Liverworts and mosses first cover the bare and rugged surface, when not a vegetable or any other kind is capable of subsisting there, they flourish, bear fruit, and decay; and the mould they produce forms an appropriate bed for the higher order of plant-seeds which are floating in the breeze or swimming on the deep. Birds next alight on the new-formed rock, and sow with interest the seeds of the berries, or the eggs of the worms and insects on which they had fed, and which pass through them without injury. Thus the vegetable mould becomes enriched with animal materials; and the whole surface is progressively covered with herbage, shaded by forest trees, and rendered a proper habitation for man and the domestic animals that attend upon him.

"The tide that makes a desolating inroad on one side of a coast throws up vast masses of sand on the opposite. The lygeum or sea-mat weed, that will grow on no other soil, thrives here and fixes it, and prevents it from being washed back or blown away. Thus fresh lands are formed, fresh banks upraised, and the boisterous sea repelled by its own agency, and there are a variety of other plants whose roots or ramifications have an equal tendency to fix the quicksand, and produce the same effect: such, especially, as the

elymus arenarius, arundo arenarius, triticum repens, and several species of the willow *."

Mr. Anthony Tatlow, probably copying some previous experiments of Sir Thomas Hyde Page, Bart. has ingeniously employed the common furze for the same purpose; and by forming it into an extensive hedge, has made the sea produce a valuable and regular embankment of its own sand. His account of this ingenious contrivance, as communicated to the Board of Agriculture, A.D. 1800, is as follows:—

"The embankment against the sea, that I mentioned when last at the Museum, is upon the estate of the Earl of Ashburnham, at Pembrey, in the county of Carmarthen, whither his lordship sent me upon his coal and other business, and with directions to see if I could devise any method of preventing the sea from making further incroachment upon his property, which it had been doing for many years, and particularly in October 1795, had broke in and covered many hundred acres, damaged the houses, buildings, stack-yards, and gardens; and it was the general opinion, that a regular embankment must be formed, which would cost some thousand pounds, he having several miles of coast. The view that I first took was upon a very windy day, and the shore an entire sand, which extended at low water many miles. In riding along, I perceived that any piece of wood, or accidental impediment to the course of the sand, raised a hill: it immediately occurred to me, that by making a hedge at the weak and low places, with wings to catch the sand as the wind blew it in different directions, I should obtain the desired effect. I therefore directed stakes nine feet long to be cut, and drove one foot and a half into the sand, at two feet and half distance from each other; betwixt which I had furze interwove, so as to form a regular furze hedge seven feet and a half high. Of this, since last June, I have done eleven hundred and thirty-seven yards; and in October last when I was there, a great deal of the hedge was covered, and since that time I am informed by letter, that a great deal more of it is so; and that the neighbouring inhabitants draw great comfort to themselves, from the security my furze embankment

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* We are indebted for these remarks to the use of an unpublished Work of a literary friend, well known to the world. EDITOR.

gives them, as its present appearance plainly evinces, that at a trifling expense, I can secure Lord Ashburnham's estate from being inundated; for, whenever the first hedge is not high enough to prevent the sea overflowing, another may be built upon the sand formed by that hedge, and so on in succession, till it is perfectly safe."

Similar means have not only been employed to prevent encroachments from the sea; but in various instances to gain land from it. It often happens, however, that the machinery must here be somewhat more complex, and intersected with drains and sluices. One of the simplest schemes of this kind which we have lately met with is the following by the Rev. Bate Dudley, which we shall copy in his own words, as communicated to the Society for the Encouragement of Arts, Manufactures and Commerce, and for which he received the gold medal.

" A tract of land, which I inclosed on the same line of coast within this parish about eleven years ago, (for which I was then honoured with the Society's gold medal) being already under a profitable course of tillage, I was induced to undertake the present inclosure, as a lessee of the collegiate estate of St. Paul's. The front line of embankment against the sea is nearly one mile in length, and, with the returning banks on each wing to the old wall, forms an inclosure of contents, as expressed in the certificate already in your possession. The whole of the embankment is composed of earth alone, borrowed from the irregular salting land in the front, called *chatts*, and taken at the limited distance of twelve feet from the base of the new work, to leave a sufficient foreland for its protection. I found, from experience, in my former embankment, that I had not given it a sufficient angular declension in front, for an easy ascent and descent of the waves. This error was therefore corrected in the last work. I began it on a base of thirty-two feet, and wrought it to the height of seven feet, leaving it a plane of five feet on the top, and making the land-side of the embankment, as nearly perpendicular as the security of the base would allow.

" Within, on the land-side, is cut a ditch, twelve feet wide, five feet deep, and four feet at bottom; the earth from which was thrown into the mound. My former sea-embankment, in Bradwell parish, had nearly given way to the great inundating tide of February 1792, from this erection of new earth being made on the surface. To guard against similar danger in the present work, a

spit deep trench, six feet wide, was previously cut along the centre of the whole line, on which the mound was to rest; this, by admitting the new earth into an incorporate adhesion with the base soil, renders a future separation almost impossible. Before this, the main rills had been filled and rammed, to give these parts equal solidity with the rest.

"The whole operation was performed by a gang of twelve sea-wallers, with barrows and planks only, at one pound ten shillings the marsh-rod, of twenty feet, and perfectly inclosed in seven months: but, it must be observed, that the soil, composed of rich vegetable matter, is without one particle of stone or gravel, and cuts with an iron edged scoop-tool, so as to load the barrows with great facility. At each end of the front line is laid an out-fall gutter, or sluice, through the whole embankment, five feet in width, by three deep deep, clear in the run; and another of smaller dimensions in the centre, for discharging the land waters freely to sea. The construction of these aqueducts is too well known to require farther description here: probably, however, the little addition given to those erected on this occasion may be found of some use. Observing it often happen, that, either from accident or design, the outward lid of the sea-sluices remained open, and admitted the tide to the great injury of the fresh waters within the marshes, I introduced here a light fly-lid within the centre of each sluice, which is out of reach, and yields to the slightest pressure of the water going out; but shuts closely against that of the tide, when it passes inwardly the external flap. These sluices are laid upon as solid a foundation as can artificially be made on such soils, to prevent the crabs, and other sea-fish, from undermining them, which must otherwise be the case. The frame and flooring are of fir, which lies under water as durable as oak.

"The land thus inclosed is partitioned into four nearly equal parts, by new out-ditches, twelve feet wide, five deep, and four at the bottom, which, with small intersecting rills, from various parts, give the whole a good drainage of its salts, on the fall of heavy rains: and, by a course recently made from a distant brook, each division of this land is now amply supplied with fresh water. Not less than eight hundred South-Down sheep, and from sixty to eighty horses, are almost constantly grazed, and even winter thereon remarkably well. The established opinion of the best farmers of

the country was, that land, thus taken from the sea, would not grow corn under thirty years at least after their inclosure. But as no experiment had been made, by which this fact could be clearly ascertained, as soon as I had shut out the sea from a part of it, about six yards square were immediately dug, and sown with horse-beans and oats, which, though the summer proved very dry, and consequently unfavourable, produced of each a fair return of sound good corn; and the last harvest the same spot being sown with wheat, yielded an excellent crop. The next spring I mean to try it with barley and turnips. My first inclosed lands in this parish have produced two succeeding crops of fine oats, and are now growing a very promising breadth of rape for seed.

"It may here be remarked, that the lower oozy parts of the new inclosure, on which no vegetable ever grew before, begin to be coated with various grasses; and as the saline parts die away in other spots, for want of their natural moisture, fresh grasses replace them, so that the whole is now nearly covered with grazing plants of good quality, amongst which appear the different *clovers*, *trefoil*, and *rye-grass*, &c. Hence I conclude, but contrary to the general opinion, that though all these grew artificially from seed sown, it does not follow of necessity that they cannot be produced without. I think that the natural operation of the sun and air, upon certain soils will alone effect it; and my experience in lands taken from the sea confirms very strongly this opinion."

The construction of canals, reservoirs, locks, piers and quays, are dependent upon the same principles, extended to a more scientific survey. In this view the art of embankment, observes Dr. Young, is a branch of architecture entirely dependent on hydrostatical and hydraulic principles. In Holland, and in some parts of Germany, this art is indispensable to the existence of large tracts of country; and even in this island, it has been of extensive utility, in gaining and securing ground on the sea coast. The construction of canals, and the management of rivers and harbours, are also dependent on the same principles; and these important subjects have been discussed by various writers, in many copious treatises, expressly devoted to hydraulic architecture.

When a bank or dike is to be constructed, it must be composed of materials capable of resisting, by their weight, the effort of the fluid to overturn them; by their lateral adhesion, the force tending

to thrust them aside horizontally; and by their density and tenacity, the penetration of the water into their substance. If the water be in motion, they must also be able to resist its friction, without being carried away by it, and they must be arranged in such a form, as to be least liable to be undermined. For many of these reasons, the surface of the bank exposed to the water must be inclined to the horizon: the line expressing the general direction of the pressure of the water ought to be confined entirely within its substance, so that no force thus applied may be able to overturn it as a whole; and this condition will always be fulfilled, when the sides of the bank make an angle with each other not less than a right angle. The pressure acting on a bank thus inclined will also tend to condense the materials, and to increase their lateral adhesion, and the particles will become less liable to crumble away by their weight, than if the surface were more nearly vertical. For embankments opposed to the sea, a bank much inclined has also the additional advantage of breaking the force of the waves very effectually. An embankment of this kind is usually furnished with drains, formed by wooden pipes or by brickwork, closed by falling doors, or valves, which allow the water to flow out at low water, but do not permit the tide to enter. To prevent the penetration of the water, clay is often used, either mixed with gravel, or sunk in a deep trench cut on each side of the canal or reservoir.

The greater or less velocity of a river must determine what substances are capable of withstanding its tendency to disturb them; some are carried away by a velocity of a few inches in a second, others remain at rest when the velocity amounts to several feet. But in general, the velocity of a river is sufficient to produce a gradual transfer of the particles of its bed, which are shifted slowly downwards, towards the sea, being occasionally deposited in those parts where the water has least motion, and serving at last to form the new land, which is always advancing into the sea, on each side of the mouth of a large river. It has been recommended, as a good form for a navigable river or canal, to make the breadth of the horizontal bottom one-fifth of that of the surface, and the depth three-tenths.

If a canal or a reservoir were confined by a perpendicular surface of boards, and it were required to support it by a single prop, the prop should be placed at the distance of one-third of the whole

height from the bottom; but it would be always more convenient in practice to fix the side of the reservoir at the bottom, than to allow the whole pressure to be supported by the prop, and it might also be strengthened by means of ribs, thicker below than above, so as to produce an equal strength throughout, wherever the prop might be placed: but if the side were formed of a single plank, of uniform thickness, the strain would be most equally divided by placing the prop very near the middle of its height.

The strength of the materials employed for flood-gates and sluices requires to be determined according to the principles, which are usually laid down, in treating of the passive strength of substances used for purposes simply mechanical; but the calculations become in this case much more intricate. Thus, if we have a circular plate or plank, of a uniform elastic substance, constituting the bottom of a pipe or cistern, and simply supported at the circumference, a very complicated calculation is required for determining the proportion of its strength to that of a square plate of the same breadth, supported only at two opposite ends, since at each point of the circular piece, there are two curvatures which require to be considered. The square plate will support a column of fluid twice as heavy as the weight which would break it, if placed at its centre; and if the calculation be correct, a circular plate will support a height of water nearly 16-7ths as great as a square plate. But for ordinary purposes, it will be sufficient to consider the strength as derived only from the resistance opposed to the flexure in one direction, since the additional strength, obtained from the lateral supports, may very properly be neglected, as only assisting in affording that additional security which is always necessary, to compensate for any accidental effects of the materials. It has been asserted that the strength of a square plate is doubled when it is supported on both sides; but this appears to be a mistake.

We may, therefore, be contented with determining the strain on the materials in that direction in which they afford the greatest resistance, either from the shorter distance between the supports, or by the disposition of the fibres; and it will be always most eligible to combine these circumstances, so that the fibres of the wood may be arranged in the direction of the shortest dimensions of the sluice. If a sluice be supported above and below only, the greatest strain will be at the distance of about 3-7ths of its height from

the bottom; and it is at this point that the greatest strength is required. But if the boards forming the sluice be fixed across it, in horizontal directions, their strength must be greatest at the bottom.

In the construction of flood-gates, the principles of carpentry must be applied in a manner nearly similar to that which serves for the determination of the best forms of roofs. The flood-gates, if they are double, without a solid obstacle between them, must meet at an angle: and when this angle is very open, the thrust against the walls or hinges must necessarily be very great. If, however, the angle were too acute, the flood-gates would require to be lengthened, and in this case their strength would be far more diminished than that of a roof similarly elevated, since the hydrostatic pressure acts always with full force in a perpendicular direction. The thickness required for each flood-gate may be determined in the same manner as the thickness of a sluice.

Where a sluice-board of considerable dimensions is to be occasionally raised, it may be necessary to ascertain the force which will be required for overcoming its friction; this friction is nearly proportional to the whole pressure of the water, and may be found, with sufficient accuracy, in pounds, by multiplying the square of the depth of the sluice, in feet, by ten. Thus, if the depth be three feet, the friction or adhesion will be about 90 pounds for each foot of the breadth.

If the side of a canal gives way, it is sometimes of consequence to prevent, as much as possible, the escape of the water. For this purpose it is usual to have doors or valves in various parts of the canal, which, when the water is at rest, lie nearly flat at the bottom; but when it begins to run over them, with a considerable velocity, they are raised by its force, and put a stop to its motion.

The utility of the introduction of canals into a commercial country may be estimated in some measure by the effect of the same labour, employed in removing weights by land carriage and by water. Thus, a single horse can scarcely draw more than a ton weight on the best road, but on a canal, the same horse can draw a boat of 30 tons at the same rate.

The construction of piers and quays, and the management of harbours, are also important departments of hydraulic architecture; it often happens that besides the application of the general princi-

ples of mechanics and hydrostatics to these purposes, the peculiar circumstances of the case may indicate to an ingenious artist a mode of performing the required work in an effectual and economical manner. We may find a good example of such an arrangement, in the account given, by Mr. Smeaton, of the method which he adopted for the improvement of the port of Ramsgate, and which indeed resembles some that had been before employed in similiar cases: by forming a large excavation, which is furnished with flood-gates, and is constantly filled at high water, he has procured a number of artificial torrents, which escape through the sluices, and become powerful agents for carrying away the matter deposited by the sea, and tending to impede the navigation of the harbour.

[*Communications to the Board of Agriculture. Trans. of the Society of Arts, &c. Young's Nat. Phil. Editor.*

SECTION XIII.

Table of Heights, in English feet, from the level of the Sea.

THIS valuable comparative estimate we take as laid down by Dr. Young, from the measurements of Deluc, Shuckburgh, Roy, Bouguer, and others.

The Caspian Sea, lower by	306
The Thames, at Hampton, Roy	14⅓
The Tiber at Rome	33
The Seine at Paris, mean height	36½
The Thames, at Buckingham Stairs fifteen feet and a half below the pavement in the left hand arcade	43

By barometrical comparison with the Seine and the Mediterranean, but this height is probably too great. Roy supposes the low water of the spring tides at Isleworth to be only one foot above the mean surface of the ocean. He allows seven feet for the difference of the low water at the Nore and at Isleworth, taking 18 feet for the height of the spring tide, adds one-third of this for the mean height of the sea. At Hampton the Thames is thirteen feet and one-third above low water mark at Isleworth.

The pagoda in Kew gardens from the ground	116½
The west end of the Tarpeian rock	151
The Palatine hill	166
The Claudian aqueduct, bottom of the canal	208
The Janiculum	293
The cross at St. Paul's, from the ground	340
St. Peter's, summit of the cross	535
From the ground 471	
Arthur's seat, from Leith pier head	803
Lake of Geneva	1230
Its greatest depth 393	
Mount Vesuvius, base of the cone	2021
Saddleback	3048

Ben Lomond	3180
Skiddaw	3270
Halvellyn	3324
Chamouny, ground floor of the inn	3367
Cross fell	3390
Pendle	3411
Table Mount, Cape	3454
Schehallion	3461
Ben Gloe	3472
Snowdon	3555
Ben Muir	3723
Ben Lawers	3858
Pennygant	3930
Mount Vesuvius, mouth of the crater	3938
Ingleborough	3987
Wheruside	4050
Ben Nevis	4350
Hecla	4887
Pic Ruivo, Madeira	5141
Summit of Mount Jura	5523
Summit of the Mole	6113
Mont Cenis à la poste	6261
Pic de los Reyes, Pyrenees	7620
Monte Velino, Appennines	8397
City of Gondar, Abyssinia	8440
Canigou, Pyrenees	8544
Summit of Mont Cenis	9212
Pic du Midi, Pyrenees	9300
Quito	9377
Monte Viso	9997
Glaciére de Buet	10124
Etna	10954
Pike of Teneriffe, Borda	11022
Pike of Teneriffe, old estimate	15084
Pic d'Ossano, Pyrenees	11700
Aiguille d'Argentière	13402
Ophir in Sumatra, Marsden	13842
Monte Rosa, Alps	15084
Summit of Mont Blanc	15669
Pichincha	15670
Antisana	19290
Chimbroaçoa	19595

It may be observed with respect to General Roy's calculation of the mean height of the sea, that it does not appear that in rivers, or even in narrow seas, we ought to add one-third of the height of the tides only to that of low water, in order to find the level; for it is probable that even the original tides may often resemble those of lakes, where, for want of breadths, the effects of a spheroidical tide cannot take place, and the elevation and depression are very nearly equal.

EDITOR.

CHAP. XXXIII.

OUTLINE OF HYDROSTATICS.

SECTION I.

General Propositions.

A FLUID is a body, the particles of which, when they are left to themselves, are all in equilibrio, or are ready to move upon the smallest force being applied to any of them. All the particles of fluids gravitate as well as those of solids. A perfect fluid ought to have no viscosity; but among liquid bodies we are acquainted with none that are entirely free from this property. The following propositions comprehend the principles of hydrostatics. The word *fluid* is used in most of them, instead of *liquid*, because several of these propositions apply to aërial fluids as well as liquids; and stating such, generally, will save us some repetition hereafter.

1. The surface of every fluid when at rest is horizontal, or perpendicular to the direction of gravity. It will at once be perceived, that when the extent of surface of the fluid is considerable, instead of being flat it will assume perceptibly the form of the segment of a sphere. For example, if a pond extends two miles every way, it can be shewn that the centre is eight inches higher than the sides. The quantity of curvature increases as the square of the arches described. Hence in levelling, a correction is necessary for this curvature, and it is usually made in this way: If D be the distance in miles, two-thirds of D^2 is equal to the correction in feet.

2. The fluid in a vessel being at rest, and subjected to the sole action of gravity, every particle of it is subjected to the same pressure every way: and the pressure is equal to the perpendicular column of water above the particle.

3. The pressure of water upon the sides of the vessel is equal to the greatest height of the water, without any regard to the extent of its upper surface. This is what is usually called the hydrostatical

paradox; because, in consequence of it, a very small quantity of water may be made to produce all the effects of a very great weight. Mr. Bramah's very ingenious press is founded upon this property of fluids. If the side and bottom of a vessel be equal; then the pressure on the bottom is twice as great as on the sides. Hence, if we wish to inclose a pond of water by a wall, it is obvious that the thickness of the wall at the bottom must be greater than at the top, as it has a much greater pressure to withstand. If the wall at the bottom be $\frac{2}{5}$ths of the height of the water, it will just balance the pressure of the water. A secure wall would require to be thicker.

4. When a body floats in water, it loses a portion of its own weight, just equal to that of the water which it displaces. The same proposition holds if the body be plunged entirely under the surface; in which case the bulk of water displaced is just equal to the bulk of the body immersed. This principle was first observed by Archimedes, and he founded on it the method of ascertaining the specific gravity of bodies, as at present practised. Let w be the weight of any body in air, w′ its weight when immersed in water, then w − w′ is the weight of the water equal to the bulk of the body. Let 1 be the specific gravity of water, and *s* the specific gravity of w, then we have $1 : s :: w - w' : w$; which gives us $s = \frac{w}{w - w'}$, the specific gravity required. As the weight of water varies with the temperature, it is usual to take specific gravities at the temperature of 60°.

5. When a body floats in water it affects a particular position, and this position is such, that the line which joins the centre of gravity of the body and the centre of gravity of the immersed part, is always vertical. Hence a body floating in water may have such a form as to have *no stability*, but to float indifferently in any position whatever. The form must be such, that the centre of gravity of the immersed part always retains the very same position, whatever part of the body is under water. This is obviously the case with a sphere: or a body floating in water may have a great deal of stability or tendency to return to a particular position: or it may have a particular position which it prefers, but from which it is very easily driven. Stability is obviously an important requisite in ship-building. Now the lower the centre of gravity of a ship is below

the deck, the greater its stability; but if it be too low, the ship returns to the vertical position with such celerity as to endanger the masts *.

SECTION II.

Motion and Resistance of Fluids.

HOWEVER satisfactory the general principles of motion may be, when applied to the action of bodies on each other, in all those circumstances which are usually included in that branch of natural philosophy called mechanics, yet the application of the same principles in the investigation of the motions of fluids, and their actions on other bodies, is subject to great uncertainty. That the different kinds of airs are constituted of particles endued with repulsive powers, is manifest from their expansion when the force with which they are compressed is removed. The particles being kept at a distance by their mutual repulsion, it is easy to conceive that they may move very freely among each other, and that this motion may take place in all directions, each particle exerting its repulsive power equally on all sides. Thus far we are acquainted with the constitution of these fluids; but with what absolute degree of facility the particles move, and how this may be effected under different degrees of compression, are circumstances of which we are totally ignorant.

In respect to those fluids which are denominated liquids, we are still less acquainted with their nature. If we suppose their particles to be in contact, it is extremely difficult to conceive how they can move among each other with such extreme facility, and produce effects in directions opposite to the impressed force without any sensible loss of motion. To account for this, the particles are supposed to be perfectly smooth and spherical. If we were to admit this supposition, it would yet remain to be proved how this would solve all the phenomena, for it is by no means self-evident that it would. If the particles be not in contact, they must be kept at a distance by some repulsive power. But it is manifest that these particles attract each other, from the drops of all perfect liquids

* There are two excellent papers in the Transactions on the stability of ships, by Mr. Atwood. Phil. Trans. 1796, Vol. lxxxvi. p. 46; and 1798, vol. lxxxviii. p. 201.

affecting to form themselves into spheres. We must therefore admit in this case both powers, and that where one power ends the other begins, agreeably to Sir Isaac Newton's * idea of what takes place, not only in respect to the constituent particles of bodies, but to the bodies themselves. The incompressibility of liquids (for I know no decisive experiments which have proved them to be compressible) seems most to favour the former supposition, unless we admit, in the latter hypothesis, that the repulsive force is greater than any human power which can be applied. The expansion of water by heat, and the possibility of actually converting it into two permanently elastic fluids, according to some late experiments, seem to prove that a repulsive power exists between the particles; for it is hard to conceive that heat can actually create any such new powers, or that it can of itself produce any such effects. All these uncertainties respecting the constitution of fluids must render the conclusions deduced from any theory subject to considerable errors, except that which is founded on such experiments as include in them the consequences of all those principles which are liable to any degree of uncertainty.

A fluid being composed of an indefinite number of corpuscles, we must consider its action, either as the joint action of all the corpuscles, estimated as so many distinct bodies, or we must consider the action of the whole as a mass, or as one body. In the former case, the motion of the particles being subject to no regularity, or at least to none that can be discovered by any experiments, it is impossible from this consideration to compute the effects; for no calculation of effects can be applied when produced by causes which are subject to no law. And in the latter case, the effects of the action of one body on another differ so much, in many respects, from what would be its action as a solid body, that a computation of its effects can by no means be deduced from the same principles. In mechanics, no equilibrium can take place between two bodies of different weights, unless the lighter acts at some mechanical advantage; but in hydrostatics, a very small weight of fluid may, without its acting at any mechanical advantage whatever, be made to balance a weight of any magnitude. In mechanics, bodies act only in the direction of gravity; but the property which fluids have of acting

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* See his Optics, Que. 31.—Orig.

equally in all directions, produces effects of such an extraordinary nature as to surpass the power of investigation. The indefinitely small corpuscles of which a fluid is composed, probably possess the same powers, and would be subject to the same laws of motion, as bodies of finite magnitude, could any two of them act on each other by contact; but this is a circumstance which certainly never takes place in any of the aërial fluids, and probably not in any liquids. Under the circumstances, therefore, of an indefinite number of bodies acting on each other by repulsive powers, or by absolute contact, under the uncertainty of the friction which may take place, and of what variation of effects may be produced under different degrees of compression, it is no wonder that our theory and experiments should be so often found to disagree.

Sir Isaac Newton seems to have been well aware of all these difficulties, and therefore in his Principia he has deduced his laws of resistance, and the principles on which the times of emptying vessels are founded, entirely from experiment. He was too cautious to trust to theory alone, under all the uncertainties to which he appears to have been sensible it must be subject. He had, in a preceding part of that great work, deduced the general principles of motion, and applied them to the solution of problems which had never before been attempted; but when he came to treat of fluids, he saw it was necessary to establish his principles on experiments; principles not indeed mathematically true, like his general principles of motion before delivered, but, under certain limitations, sufficiently accurate for all practical purposes.

The principle to be established in order to determine the time of emptying a vessel through an orifice at the bottom, is the relation between the velocity of a fluid at the orifice and the altitude of the fluid above it. Most writers on this subject have considered the column of fluid over the orifice as the expelling force; whence some have deduced the velocity at the orifice to be that which a body would acquire in falling down the whole depth of the fluid; and others that acquired in falling through half the depth, without any regard to the magnitude of the orifice; whereas it is manifest from experiment, that the velocity at the orifice, the depth of the fluid being the same, depends on the proportion which the magnitude of the orifice bears to the magnitude of the bottom of the vessel, supposing, for instance, the vessel to be a cylinder standing on its

base; and in all cases the velocity, *cæteris paribus*, will depend on the ratio between the magnitude of the orifice and that of the surface of the fluid. Conclusions thus contrary to matter of fact show, either that the principle assumed is not true, or that the deductions from it are not applicable to the present case. The most celebrated theories on this subject are those of D. Bernouilli and M. D'Alembert; the former deduced his conclusions from the principle of the *conservatio virium vivarum*, or as he calls it, the *equalitas inter descensum actualem ascensumque potentialem*, where, by the *descensus actualis* he means the actual descent of the centre of gravity, and by the *ascensus potentialis*, he means the ascent of the centre of gravity, if the fluid which flows out could have its motion directed upwards; and the latter from the principle of the equilibrium of the fluid. This principle of M. D'Alembert leads immediately to that assumed by D. Bernoulli, and consequently they both deduce the same fluxional equation, the fluent of which expresses the relation between the velocity of the fluid at the orifice, and the perpendicular altitude of the fluid above it. How far the principles here assumed can be applied in our reasoning on fluids, can only be determined by comparing the conclusions deduced from them with experiments.

In order to determine whether there was any pressure of the fluid against the sides of the pipes as it passed through in all their different situations, some small holes were pierced in them at different parts. In the cylindrical pipes, and those in the form of increasing cones, the fluid passed by the holes without being projected out, or without having the least tendency to issue through them; but in the decreasing cones the fluid spouted out at the holes. In the former cases therefore there was no pressure against the sides of the pipes, but in the latter case there was.

In respect to the motion of the fluid through any of the pipes, I found no difference whether I stopped the pipe at the end of the tube which enters into the vessel, in which case the motion began when the tubes were empty, or whether at the other end, in which case they were full at the commencement of the motion. That the fluid should flow into the pipe faster than it would through an orifice, may probably, in part at least, be owing to the adhesion of the fluid to the pipe, and be thus explained. Though the horizon-

tal motion of the fluid towards the orifice accelerates the velocity after it escapes from the vessel by contracting the stream, yet it must diminish the velocity at the orifice; that is, if the same perpendicular motion were to take place without the horizontal motion, the fluid would flow out faster; for as any motion in a fluid is immediately communicated in every direction, the horizontal motion will produce a motion upwards, and in some degree obstruct the descent of the fluid. If therefore this horizontal motion could be taken away, or any how diminished, the fluid would flow out with a greater velocity. Now if a pipe be fixed, the fluid at the bottom of the vessel flowing towards the orifice will, by its adherence to the vessel, continue to adhere to the sides of the pipe as soon as it arrives there, and by this means almost all the horizontal motion will be destroyed, and converted into a perpendicular motion; for the horizontal motion arises principally from the fluid which flows from and very near to the bottom, where the whole motion is very nearly in that direction. This motion therefore being thus nearly destroyed, the fluid will be less interrupted at the orifice, and consequently will flow out with a greater velocity. But why the velocity should also be increased either by increasing the length of the pipe, or making it an increasing cone, under certain limitations, is a circumstance which, I confess, I can give no satisfactory reason for.

The above-mentioned experiments were made principally with a view to ascertain how far the theory of the motion of fluids can be applied; and the inquiry has led to several circumstances which probably have not been observed before. That the theory is not applicable in all cases, is manifest; but that it brings out conclusions in many instances which agree very well with experiment, is undoubtedly true. This tends to show, either that the common principles of motion cannot be applied to fluids, and that the agreement is accidental; or that under certain circumstances and restrictions the application is just. Which of these is the case, is not perhaps easy for the mind to satisfy itself about. Nothing however which is here said, is done with any view to detract from the merit of those celebrated authors. They have manifested uncommon penetration, and carried their inquiries on the subject to an extent, that nothing farther can be hoped for or expected; and if they had done nothing else in science, this alone would have ranked them among

the very first mathematicians. The fault has been *non artificis sed artis.*

[*Vince. Phil. Trans.* 1795.

SECTION III.

On the Friction and Velocity of Currents.

THE effects of friction is particularly exemplified by the motions of rivers, in which almost the whole force of gravity is employed in overcoming it. When the inclinations and dimensions of a river continue uniform, the velocity is also every where equal; for otherwise the depth would become unequal: here, therefore, the force of gravitation must be an exact counterpoise to the resistance which is to be overcome, in order that the water may flow with its actual velocity; this velocity having been originally derived from the effect of a greater inclination near the origin of the river. When the river is thus proceeding, with an equable motion, it is said to be in train; and it is obvious that no increase of its length will produce any alteration in its velocity. There is, therefore, a very material difference between the course of a river, and the descent of a body, with an accelerated motion, along an inclined surface. For when a solid body is placed on an inclined plane, the force of friction is either great enough to overpower its relative weight, and to retain it at rest, or else the friction is constantly less than the gravitation, and the motion is always accelerated. But the resistance to the motions of fluids arises principally from different causes; not from the tenacity of the fluids, which, where it exists, is a force nearly uniform, like that of friction, but principally from the irregular motions and mutual collisions of their particles; and in this case, according to the laws of mechanics, it must vary nearly in proportion to the square of the velocity. For when a body is moving in a line of a certain curvature, the centrifugal force is always as the square of the velocity; and the particles of water in contact with the sides and bottom of a river or pipe, must be deflected, in consequence of the minute irregularities of the surfaces on which they slide, into nearly the same curvilinear paths, whatever their velocity may be, so that the resistance, which is in great measure occasioned by this centrifugal force, must also vary as the square of the velocity. Thus also the curvature assumed by the outline of a stream of wa-

for issuing from a simple orifice, which constitutes the contraction already described, is very nearly the same, whatever the velocity may be: nor does the friction increase with the pressure, as is demonstrated by an experiment of Professor Robison on the oscillation of a fluid through a bent tube, terminated by two bulbs, which were performed in the same time, whether the tube was in a horizontal or in a vertical position. Mr. Coulomb has also proved the same fact by experiments on the vibrations of bodies immersed in fluids, and suspended by twisted wires; he finds that precisely at the surface, the friction is somewhat greater than at any depth below it: he also considers a certain part of the friction as simply proportional to the velocity, and a small portion only, in common fluids, as perfectly independent of it.

It is obvious that wherever the friction varies as the square of the velocity, or even when it increases in any degree with the velocity, there must always be a limit, which the velocity can never exceed, by means of any constant force, and this limit must be the velocity at which the resistance would become equal to the force. It is for this reason that a light body, descending through the air, soon acquires a velocity nearly uniform; and if it be caused, by any external force, to move for a time more rapidly, it will again be speedily retarded, until its velocity be restored very nearly to its original state. In the same manner the weight of the water in a river, which has once acquired a stationary velocity, is wholly employed in overcoming the friction produced by the bottom and the banks.

From considering the effect of the magnitude of the surface exposed to the friction of the water, in comparison with the whole quantity contained in the river, together with the degree in which the river is inclined to the horizon, we may determine, by following the methods adopted by Mr. Buat, the velocity of any river of which we know the dimensions and the inclination. Supposing the whole quantity of water to be spread on a horizontal surface, equal in extent to the bottom and sides of the river, the height, at which it would stand, is called the hydraulic mean depth; and it may be shown that the square of the velocity must be jointly proportional to the hydraulic mean depth, and to the fall in a given length. If we measure the inclination by the fall in 2800 yards, the square of the velocity in a second will be nearly equal to the product of this fall multiplied by the hydraulic mean depth. For example, in the

Ganges, and in some other great rivers, the mean depth being about 30 feet, and the fall four inches in a mile, the fall in 2800 yards will be about $6\frac{1}{2}$ inches, which, multiplied by 360 inches, gives 2340 inches for the square of the mean velocity, and $48\frac{1}{3}$ inches, or about four feet for the mean velocity in a second, that is, not quite three miles an hour, which is the usual velocity of rivers moderately rapid. If, however, great precision were required in the determination, some further corrections would be necessary, on account of the deviation of the resistance from the exact proportion of the squares of the velocities: since the friction, as we have already seen, does not increase quite so fast as this.

It is obvious that the friction of a fluid, moving on the surface of a solid alone, would not produce any material retardation of its motion, if the particles of the fluid themselves were capable of moving on each other, without the least resistance; for in this case a small portion of the fluid, in immediate contact with the solid, might remain at rest, and the remaining mass of the fluid might slide over this portion without any retardation. It appears, however, that the water in contact with the bottom of a river moves with a very considerable velocity, and the water next above this only a little faster, so that the velocity increases almost uniformly as we ascend towards the surface. It follows, therefore, that the resistance must be much greater where the particles of water slide on each other, than where they glide along the surface of a solid. This internal friction operates gradually throughout the water; the surface being retarded by the particles immediately below it, those particles by the next inferior stratum, and each stratum being actuated, besides its own relative weight, by the friction of the water above, tending to draw it forwards, and by that of the water below, tending still more to retard it; the retardation being communicated, from below upwards, in such a manner as to be every where equivalent to the relative weight of the water above the part considered. It appears from observation, that when we have determined the mean velocity in English inches, we may find the superficial velocity, very nearly, by adding to it its square root, and the velocity at bottom, by subtracting from it the same number; thus the square root of $48\frac{1}{3}$ being nearly 7, the superficial velocity of the Ganges will be about 55 inches, or 4 feet 7 inches in a second, and the velocity at the bottom $41\frac{2}{3}$. There are, however, frequent irregularities in the pro-

portions of the velocities at different depths, and it has sometimes been observed, perhaps on account of the resistance of the air, that the velocity is a little less, immediately at the surface, than a few inches below it.

For similar reasons, the velocity of a river is also generally greater in the middle than at the sides; and the motion of the particles in the middle must be retarded, not only by those which are below them, but also by those on each side, while these, on the contrary, are dragged on by the water in the middle: the middle parts tend, therefore, to draw the sides towards them, which they cannot do, without lowering the surface of the fluid next to the banks, in such a degree as to make the difference of level an equivalent to this tendency to approach the middle. This appears to be the reason, why the surface of a large river may generally be observed to be slightly convex, or a little elevated in the middle.

The course of a river is sometimes interrupted by a *were* or a fall, natural or artificial; in such cases the velocity may be calculated in the same manner as when a fluid is discharged from a reservoir through an aperture of considerable height: supposing the whole section of the were to be such an aperture, in a vessel so much higher, that the velocity of a fluid issuing from it at the upper part of the aperture would be precisely equal to the actual velocity of the river. The extent of the swell caused by a were, or by any partial elevation thrown across the bed of a river, may also be found by first determining the height at which the surface must stand immediately above the were, and then calculating the inclination of the surface which will be required for producing the actual velocity, in the river thus made deeper; which of course will determine the situation of the surface where the water approaches the were; and this surface, which is more nearly horizontal than the general surface of the river, will be so joined to it as to have a curvature nearly uniform throughout.

It appears from calculations of the effects of various changes in the dimensions of rivers, as well as from immediate observation, that a considerable diminution of the breadth of a river at a particular place, will often produce but a small elevation of its surface. The velocity, however, may sometimes be considerably increased by such a change, and where the bottom is of a loose nature, its par-

ticles may be carried away by means of the increased velocity, and the bed of the river may be deepened.

Where a river bends in a considerable degree, it is generally remarked that the velocity of the water is greater near the concave than the convex side of the flexure, that is, at the greatest distance from the centre of its curvature. This effect is probably occasioned by the centrifugal force, which accumulates the water on that side; so that the banks are undermined, and the channel is deepened by its friction. Some authors have been led to expect that the velocity would be greater nearest to the convex bank, because the inclination of the surface must be a little greater there: but the effect of the accelerating force, in any short distance, is inconsiderable, and it is more than compensated by the want of depth. It may easily be understood, that all angles and flexures must diminish the general velocity of the river's motion, and the more as they are the more abrupt.

It has sometimes been imagined, that because the pressure of fluids is propagated equally in all directions, their motions ought also to diverge in a similar manner; but this opinion is by no means well founded, even with respect to those particles which receive their motions in an unlimited reservoir from the impulse of a stream which enters it. An experiment, which sets this fact in a clear point of view, was made long ago by Hauksbee. He produced a very rapid current of air, by means of a vessel, into which three or four times as much air as it naturally contained had been condensed by means of a syringe, and causing the current to pass through a small box, in which the bason of a barometer was placed, the mercury was depressed more than two inches in consequence of the rarefaction which the current produced in the air of the box.

Professor Venturi has also made several experiments of a similar nature on the motion of water: he observes that not only the water in contact with a stream is drawn along by it, but that the air in the neighbourhood of a jet is also made to partake of its motion. When the mouth of a pipe, through which a stream of water is discharged, is introduced into a vessel a little below the surface of the water which it contains, and is allowed to escape by ascending an inclined surface placed opposite to the pipe, and leading over the

side of the vessel, the stream not only ascends this surface without leaving any portion of itself behind, but carries also with it the whole of the water of the vessel, until its surface becomes level with the lowest part of the stream.

The effect of a jet of water, in drawing towards it a current of air, is in some measure illustrated by an experiment which is often exhibited among the amusements of hydraulics. A ball of cork, or even an egg, being placed in the middle of a jet, which throws up a pretty large stream to a moderate height, the ball, instead of falling or being thrown off, as it might naturally have been expected to do, remains nearly either stationary, or playing up and down, as long as the experiment is continued. Besides the current of air which Venturi has noticed, and which tends to support the ball in a stable equilibrium, the adhesion of the water, combined with its centrifugal force in turning round the ball, assists in drawing it back, when it has declined a little on either side, so that the stream has been principally in contact with the other side. A similar effect may be observed in the motions of the air only, as Dr. Young has shown by some experiments of which an account is published in the Philosophical Transactions. Thus, if we bend a long plate of metal into the form of the letter S, and suspend it in the middle by a thread, so that it may move freely on its centre, and if we then blow on its convex surface with a tube directed obliquely towards the extremity, instead of retreating before the blast, it will on the contrary appear to be attracted; the pressure of the atmosphere being diminished by the centrifugal force of the current, which glides along the convex surface, because it finds a readier passage in the neighbourhood of the solid, towards which it is urged by the impulse of the particles of the air approaching it on one side, and by the defect of pressure on the other side, occasioned by the removal of a certain portion of the air which it carries with it.

From considerations similar to those by which the velocity of a river is determined, we may calculate the quantity of water discharged from a pipe of any given dimensions, and in any position. The same expressions will serve for estimating the magnitude of the friction in both cases; the pipe being considered as a small river, of which the mean depth is one-fourth of its diameter: but a part only of the force of gravity is now expended in overcoming the friction, the rest being employed in producing the momentum of

of the water. We may obtain a sufficiently accurate determination of the velocity, by supposing the height of the reservoir above the orifice of the pipe to be diminished in the same proportion as the diameter of the pipe would be increased by adding to it one-fiftieth part of the length, and finding the whole velocity corresponding to four-fifths of this height. Thus, if the diameter of the pipe were one inch, and its length 100 inches, we must suppose the effective height to be reduced to one-third by the friction, and the discharge must be calculated from a height four-fifths as great as this, which may be considered as a reduc ion derived from the interference of the particles, entering the pipe, with each other's motions. If the diameter of the pipe had been two inches, the height must only have been supposed to be reduced to one-half by the friction; such a pipe would, therefore, discharge about five times as much water as the former, although of only twice the diameter; and this circumstance requires the attention of all those who are concerned in regulating the distribution of water by pipes for domestic use, or for any other purpose.

In such cases it becomes also frequently necessary to attend to the angle in which a small pipe is inserted into a larger; whenever a pipe is bent, there is a loss of force according to the degree of flexure, and to the velocity of the water, which may be calculated, if it be required; but if a pipe be fixed into another through which the water is moving very rapidly, in a direction contrary to that of the stream, its discharge will not only be much smaller than if the directions more nearly coincided, but sometimes such a pipe will discharge nothing at all; on the contrary, like the air in Hauksbee's experiment, the water which it contains may be dragged after the stream in the larger pipe.

[*Young's Nat. Phil.*]

SECTION IV.

On Siphons and Jets of Water.

It is very well known that the general weight and pressure of the atmosphere upon liquids is capable of throwing them up into tubes of a considerable height, one of whose extremities is immersed in the reservoir of the liquid made use of for this purpose, and the other constituting an exhausted receiver or vacuum. Liquids, how-

ever, are of different specific gravities, and hence the weight and pressure of the atmosphere cannot raise them all to an equal height. Thus quicksilver will ascend in an exhausted tube to the height of about thirty inches on the level of the sea, though as the air is lighter or perhaps less elastic at some times than at others, the height of the column will vary between the limits of 27 and 31 inches: and we hence obtain the useful and well known instrument denominated a barometer, concerning which we shall have occasion to speak more at large hereafter. From the greater levity of water, a column of this liquid may be sustained in the tube or pipe of a pump to a height of from 30 to 35 feet, the pipe, by means of its valve or sucker, possessing a vacuum on its upper extremity like that of the upper extremity of the barometrical tube.

It is from this curious fact that we are able, without any additional machinery, to have the water conveyed by pipes supplied from a reservoir or fountain of equal elevation to the upper stories of our houses whose height does not exceed from thirty to thirty-five feet. And hence the origin of natural or artificial *jets d'eaux*, jets of water or spouting fountains; the jet being supplied from an elevated head or reservoir by means of artificial tubes or natural channels or conductors. These tubes or conductors, whether natural or artificial, are sometimes bent, and are then called siphons, and according to the nature and complexity of the curvature, produce a variety of striking and amusing phænomena.

When a siphon, or bent tube, observes Dr. Young, is filled with a fluid, and its extremities are immersed in fluids of the same kind, contained in different vessels, if both their surfaces are on the same level, the whole remains at rest; but if otherwise, the longer column in the siphon preponderates, and the pressure of the atmosphere forces up the fluid from the higher vessel, until the equilibrium is restored; provided, however, that this pressure be sufficiently powerful: for if the height of the tube were more than 34 feet for water, or than thirty inches for mercury, the pressure of the atmosphere would be incapable of forcing up the fluid to its highest part, and this part remaining empty, the fluid could no longer continue to run.

If the lower vessel be allowed to empty itself, the siphon will continue running as long as it is supplied from the upper, with a velocity nearly corresponding to the height of that portion of the

fluid in the longer leg, which is not counterbalanced by the fluid in the shorter; that is, to the height of the surface of the upper vessel above that of the lower one, or above the end of the siphon, when it is no longer immersed; for the height of the pipe is in all cases to be considered as constituting a part of that height which produces the pressure. Thus the discharge of a pipe, descending from the side or bottom of a vessel, is nearly the same as from a similar horizontal pipe, inserted into a reservoir of the whole height of the descending pipe and of the fluid above it; and this is true even when the depth of the vessel is inconsiderable, in comparison with the length of the pipe, if its capacity is sufficient to keep the pipe running full. It appears at first sight extremely paradoxical, that the whole water discharged, each particle of which is subjected to the action of gravitation in a pipe 16 feet long, for half a second only, should acquire the velocity of 32 feet in a second, which would require, in common circumstances, the action of the same force of gravitation for a whole second, and this fact may be considered as favourable to the opinion of those, who wish to estimate the magnitude of a force, rather by the space through which it is continued, than by the time during which it acts; but if we attend to the nature of hydrostatical pressure, we shall find that the effect of the column on the atmosphere is such, as to produce, or to develope, a portion of accelerating force which is actually greater than the weight of the particles immediately concerned. If a doubt could be entertained of the truth of this theory, it might easily be removed by recurring to the general law of ascending force, since it follows from that law, that each particle, which descends in any manner through the space of 16 feet, must acquire, either for itself or some other particles, a power of ascending to the same height; and on the other hand, the event of the experiment confirms the general law. For if we fix a shallow funnel on a vertical pipe, and pour water into it, so as to keep it constantly full, while the pipe discharges itself into a reservoir, out of which the water runs through a second pipe, placed horizontally, of exactly the same dimensions with the first, the height, at which the water in the reservoir becomes stationary, will be very nearly equal to the height of the funnel above its surface, so that the same height produces the same velocity in both cases.

We may understand the action of the forces immediately con-

cerned in this experiment, by attending to the mutual effects of the water and of the atmosphere. The water entering the orifice must immediately acquire a velocity equal to that of the whole water in the pipe, otherwise there would be a vacuum in the upper part of the pipe, which the pressure of the atmosphere will not permit; and this pressure, considered as a hydrostatic force, is equal to that which would be derived in any other way from a column of the same height with the pipe, since the weight of the water in the pipe is wholly employed in diminishing the counterpressure of the atmosphere below, not only in the beginning, when it is at rest, but also while it is in motion; for that motion being uniform throughout its descent, the power of gravitation is expended in producing pressure only; so that the pressure of the atmosphere on the water in the funnel becomes completely analogous to the pressure of a reservoir of water, of the same height with the pipe. The circumstance, which causes the appearance of paradox in this experiment, exists also in the simplest case of the discharge of water; for it may be shown, that the portion of accelerating force actually employed in generating the velocity with which a stream is discharged through a small orifice, is twice as great as the pressure of the fluid on a part of the vessel equal in extent to the orifice; and in the same manner the quantity of force exerted by the atmosphere on the water in the funnel, as well as that with which the descending fluid impels the air below, is equal to twice the weight in the quantity existing at any time in the pipe.

There is, however, a limit, which the mean velocity in such a pipe can never exceed, and which is derived from the magnitude of the pressure of the atmosphere. For the water cannot enter the pipe with a greater velocity than that with which it would enter an exhausted pipe, and which is produced by the whole pressure of the atmosphere; and this pressure being equivalent to that of a column of water 34 feet high, the velocity derived from it is about 47 feet in a second: so that if the vertical pipe were more than 34 feet long, there would be a vacuum in a part of it near the funnel.

Wherever a pipe of considerable length descends from a funnel, if the supply of the fluid be scanty, and especially if it approach the orifice obliquely, the pressure of the atmosphere, and the centrifugal force of the particles which must necessarily revolve round

the orifice, will unite in producing a vacuity in the centre; and when this happens, the discharge is considerably diminished.

In order that a siphon may run, it is obvious that it must first be filled; and when it is once filled, it will continue to run till the reservoir is exhausted, as far as the level of its upper orifice. And from this circumstance, the phenomena of some intermitting springs have been explained, which only begin to run, when the reservoirs from which they originate have been filled by continued rains, and then go on to exhaust them, even though the weather may be dry. From a combination of several such siphons and reservoirs, a great number of alternations may sometimes be produced.

Since the velocity of a stream or jet issuing in any direction, out of a simple orifice, or a converging one, is nearly equal to that of a heavy body falling from the height of the reservoir, it will rise, if directed upwards, very nearly to the same height, excepting a slight difference occasioned by the resistance of the air, and by the force which is lost, in producing the velocity with which the particles must escape laterally, before they begin to descend. The truth of this conclusion is easily confirmed by experiment.

If a jet issue in an oblique or in a horizontal direction, its form will be parabolic, since every particle tends, as a separate projectile, to describe the same parabola in its range: and it may be demonstrated, that if it be emitted horizontally from any part of the side of a vessel, standing on a horizontal plane, and a circle be described, having the whole height of the fluid for its diameter, the jet will reach the plane, at a distance from the vessel twice as great as the distance of that point of the circle, through which it would have passed, if it had continued to move horizontally. And if the jet rise in any angle from the bottom of the vessel, the utmost height of its ascent will be equal to that of the point in which it would meet the same simicircle, if it continued to move in a right line, and the horizontal range will be equal to four times the distance, intercepted between the same point and the side of the vessel. This law is equally true with regard to simple projectiles: but the experiment is most conveniently exhibited in the motion of a jet.

We have hitherto considered the motions of fluids as continued principally in the same direction; but they are frequently subjected to alternations of motion, which bear a considerable analogy to the

vibrations of pendulums; thus, if a long tube be immersed in a fluid, in a vertical direction, and the surface of the fluid within the tube be elevated a very little, by some external cause, the whole content of the fluid will be urged downwards by a force, which decreases in proportion to the elevation of the surface above the general level of the vessel, and when both surfaces have acquired the same level, the motion will be continued by the inertia of the particles of the fluid, until it be destroyed by the difference of pressures, which now tends to retard it; and this alternation will continue, until the motion be destroyed by friction and by other resistance. It is also obvious, that since any two vibrations, in which the forces are proportional to the spaces to be described, are performed in equal times, these alternations will require exactly the same time for their completion, as the vibrations of a pendulum, of which the length is equal to that of the whole tube; for the relative force in the tube is to the whole force of gravity as the elevation or depression is to the whole length of the tube. Hence it follows, that if two such tubes were united below, so as to form a single bent tube, the vibrations might take place in the whole compound tube, in the same manner, and in the same time, as in each of the separate tubes; nor would the effects be materially altered if any part of the middle of the tube were in a horizontal or in an oblique direction, provided that the whole length remained unaltered. In such a tube also, all vibrations, even if of considerable extent, would be performed in the same time, and would long remain nearly of the same magnitude; but in a single tube, open below, the vibrations would continually become less extensive, and their duration would also be altered as well as their extent; besides the unavoidable resistances, which would in both cases interfere with the regularity of the effects.

Mr. Whitehurst, in the Philosophical Transactions for 1775, has given a curious account of the application of these principles in a contrivance for raising water, employed at Oulton, Cheshire, the seat of Philip Egerton, Esq. The water was contained in a reservoir, from the bottom of which there passed a pipe to the kitchen, sixteen feet below the reservoir. This pipe had two extremities; one of them furnished with a stop-cock, was for the use of the kitchen; the other furnished with a valve, terminated near the bottom of a stout vessel containing air. From the bottom of this

air vessel, there passed a tube to another reservoir, higher than the original reservoir, and destined for the brew-house. When water was drawn for the kitchen, the water in the pipe acquired, by running, a considerable velocity. Hence, when the stop-cock was shut, it acted on the valve, forced it open, and rushing into the air vessel, compressed the air which it contained. This happening every time that water was drawn for the use of the kitchen, which was very frequently, the water made its way into the brew-house reservoir, and supplied it sufficiently.

Dr. Darwin, by an application of the same principles, ingeniously obtained an artificial spring from an elevated well at a considerable distance. The following is his account of the plan pursued, as communicated to the Royal Society in 1785. "Near my house, says Dr. D., was an old well, about 100 yards from the river Derwent in Derby, and about four yards deep, which had been many years disused, on account of the badness of the water, which I found to contain much vitriolic acid, with at the same time a slight sulphureous smell and taste; but did not carefully analyse it. The mouth of this well was about four feet above the surface of the river; and the ground, through which it was sunk, consisted of a black, loose, moist earth, which appeared to have been very lately a morass, and is now covered with houses built on piles. At the bottom was found a bed of red marl, and the spring, which was so strong as to give up many hogsheads in a day, oozed from between the morass and the marl: it lay about eight feet beneath the surface of the river, and the water rose within two feet of the top of the well.

"Having observed that a very copious spring, called Saint Alkmund's well, rose out of the ground about half a mile higher on the same side of the Derwent, the level of which I knew by the height of the intervening wier to be about four or five feet above the ground about my well; and having observed that the higher lands at the distance of a mile or two behind these wells, consisted of red marl like that in the well; I concluded, that, if I should bore through this stratum of marl, I might probably gain a water similar to that of St. Alkmund's well, and hoped that at the same time it might rise above the surface of my old well to the level of St. Alkmund's. With this intent a pump was first put down for the purpose of more easily keeping dry the bottom of the old well, and a hole about 2½ inches

diameter was then bored about 13 yards below the bottom of the well, till some sand was brought up by the auger. A wooden pipe, which was previously cut in a conical form at one end, and armed with an iron ring at the other, was driven into the top of this hole, and stood up about two yards from the bottom of the well, and being surrounded with well-rammed clay, the new water ascended in a small stream through the wooden pipe. Our next operation was to build a wall of clay against the morassy sides of the well, with a wall of well-bricks internally, up to the top of it. This completely stopped out every drop of the old water; and, on taking out the plug which had been put in the wooden pipe, the new water in two or three days rose up to the top, and flowed over the edges of the well.

"Afterwards, to gratify my curiosity in seeing how high the new spring would rise, and for the agreeable purpose of procuring the water at all times quite cold and fresh, I directed a pipe of lead, about eight yards long, and ¾ of an inch diameter, to be introduced through the wooden pipe described above, into the stratum of marl at the bottom of the well, so as to stand about three feet above the surface of the ground. Near the bottom of this leaden pipe was sewed, between two leaden rings or flanches, an inverted cone of stiff leather, into which some wool was stuffed to stretch it out, so that, after having passed through the wooden pipe, it might completely fill up the perforation of the clay. Another leaden ring or flanch was soldered round the leaden pipe, about two yards below the surface of the ground, which, with some doubles of flannel placed under it, was nailed on the top of the wooden pipe, by which means the water was perfectly precluded from rising between the wooden and the leaden pipes.

"This being accomplished, the bottom of the well remained quite dry, and the new water quickly rose about a foot above the top of the well in the leaden pipe: and, on bending the mouth of this pipe to the level of the surface of the ground, about two hogsheads of water flowed from it in twenty-four hours, which had similar properties with the water of St. Alkmund's well, as on comparison both these waters curdelled a solution of soap in spirit of wine, and abounded with calcareous earth, which was copiously precipitated by a solution of fixed alkali; but the new water was found to possess a greater abundance of it, with numerous small bubbles of aërial acid or calcareous gas. The new water has now flowed about twelve months,

and seems already increased to almost double the quantity in a given time; and I think it is now less replete with calcareous earth, approaching gradually to an exact correspondence with St. Alkmund's well, as it probably has its origin between the same strata of earth."

As many mountains bear incontestable marks of having been forcibly raised up by some power beneath them; and other mountains, and even islands, have been lifted up by subterraneous fires in our own times, we may safely reason on the same supposition in respect to all other great elevations of ground. Proofs of these circumstances are to be seen on both sides of this part of the country: whoever will inspect, with the eye of a philosopher, the lime-mountain at Breedon, on the edge of Leicestershire, will not hesitate a moment in pronouncing, that it has been forcibly elevated by some powers beneath it; for it is of a conical form with the apex cut off, and the strata, which compose its central parts, and which are found nearly horizontal in the plain, are raised almost perpendicularly, and placed on their edges, while those on each side decline like the surface of the hill; so that this mountain may well be represented by a bur made by forcing a bodkin through several parallel sheets of paper. At Router, or Eagle-stone, in the Peak, several large masses of grit stone are seen on the sides and bottom of the mountain, which by their form evince from what parts of the summit they were broken off at the time it was elevated; and the numerous loose stones scattered about the plains in its vicinity, and half buried in the earth, must have been thrown out by explosions, and prove the volcanic origin of the mountain. Add to this the vast beds of toad-stone or lava in many parts of this county, so accurately described, and so well explained by Mr. Whitehurst, in his Theory of the Formation of the Earth.

Now as all great elevations of ground have been thus raised by subterraneous fires, and in a long course of time their summits have been worn away, it happens, that some of the more interior strata of the earth are exposed naked on the tops of mountains; and that in general those strata which lie uppermost, or nearest to the summit of the mountain, are the lowest in the contiguous plains. This will be readily conceived if the bur, made by thrusting a bodkin through several parallel sheets of paper, had a part of its apex cut off by a pen-knife, and is so well enplalned by Mr. Michell, in an

ingenious paper on the Phenomena of Earthquakes, published a few years ago in the Philosophical Transactions.

And as the more elevated parts of a country are so much colder than the vallies, owing perhaps to a concurrence of two or three causes, but particularly to the less condensed state of the air on hills, which thence becomes a better conductor of heat, as well as of electricity, and permits it to escape the faster; it is from the water condensed on these cold surfaces of mountains that our common cold springs have their origin; and which, sliding between 2 of the strata above described, descend till they find or make themselves an outlet, and will in consequence rise to a level with the part of the mountain where they originated. And hence, if by piercing the earth you gain a spring between the 2d and 3d, or 3d and 4th stratum, it must generally happen, that the water from the lowest stratum will rise the highest, if confined in pipes, because it comes originally from a higher part of the country in its vicinity.

[*Young's Nat. Phil. Thomson's Phil. Trans. Editor.*

SECTION V.

On Capillary Tubes and Siphons.

CAPILLARY tubes are tubes of glass, the interior aperture of which is very narrow, being only half a line, or less, in diameter. The reason of this denomination may be readily perceived.

These tubes are attended with some singular phænomena, in the explanation of which, philosophers do not seem to have agreed. Hitherto it has been easier, in this respect, to destroy, than to build up. The principal of these phænomena are as follow:

1. It is well known that water, or any other fluid, rises to the same height in two tubes which have a communication with each other; but if one of the branches be capillary, this rule does not hold good: the water in the capillary tube rises above the level of that in the other branch, and the more so, the narrower the capillary tube is.

It seemed very easy to the first philosophers, who beheld this phænomenon, to give an explanation of it. They supposed that the air, which presses on the water in the capillary tube, experiences some difficulty in exercising its action, on account of the narrowness of the tube; and that the result must be an elevation of the fluid on that side.

This however was not very satisfactory; for what reason is there to think that the air, the particles of which are so minute, will not be at perfect freedom in a tube half a line, or a quarter of a line, in diameter?

But whether this explanation be satisfactory or not, it is entirely overturned by the second and third phænomena of capillary tubes.

2. When mercury is employed, instead of water, this fluid, instead of rising in the capillary branch, to the level which it reaches in the other, remains below that level.

3. If the experiment be performed in vacuo, every thing takes place the same as in the open air. The cause of this phænomenon then is not to be sought for in the air.

4. If the inside of the tube be rubbed with any greasy matter such as tallow, the water, instead of rising above the level, remains below it. The case is the same, if the experiment be made with a tube of wax, or the quills of a bird, the inside of which is always greasy.

5. If the end of a capillary tube be immersed in water, this fluid immediately rises above the level of that in the vessel, and to the same height to which it would rise in a syphon, if one of its branches were a capillary tube, and the other of the common size; so that if the surface of the water only be touched, it is immediately attracted, as it were, to the height abovementioned, and it remains suspended at that height when the tube is removed from the water.

6. If a capillary tube be held in a perpendicular direction, or nearly so, and if a drop of water be made to run along its exterior surface, when the drop reaches its lower aperture, it enters the tube, if it be of sufficient size, and rises to the height at which it would stand, above the level, in the branch of a syphon of that calibre.

7. The heights at which water maintains itself in capillary tubes, are in the inverse ratio of the diameter. Thus, if water rise to the height of 10 lines in a tube one-third of a line in diameter, it ought to rise to the height of 20 lines in a tube one-sixth of a line in diameter, and to the height of 100 in a tube one-30th of a line in diameter.

The falling of mercury below the level in such tubes, follows also the inverse ratio of the diameters of the tubes.

9. Those persons would be deceived who should imagine, that the lightest liquors rise to the greatest height in these tubes: of aqueous liquors, spirit of wine is that which rises to the least height. In a tube in which water rises 26 lines, spirit of wine rises only 9 or 10. The elevation of spirit of wine, in general, is only the half or a third of that of water.

This elevation depends also on the nature of the glass: in certain tubes, water rises higher than in others, though their calibres be the same.

To be convinced that these effects are not produced by any thing without the tube or the liquor, it is necessary to see these phænomena, which are indeed the same in a vacuum, or in air highly rarefied, as in the air which we breathe. They vary also according to the nature of the glass of which the tube is formed; and they are different according to the nature of the fluid. The causes therefore must be sought for in something inherent in the nature of the tube, and in that of the fluid.

This cause is generally ascribed to the attraction mutually exercised between glass and water. This explanation has been controverted by Father Gerdil, a Barnabite and an able philosopher, who has done every thing in his power to overturn it. On the other hand, M. de la Lande has stood forth in its defence, and is one of those modern writers who have placed this explanation in the clearest light. The reader may consult also, on this subject, a very learned and profound memoir by M. Weitbrecht, in the Memoirs of the Imperial Academy of Sciences at Petersburgh.

When philosophers saw water rise in a capillary tube, above the level of that in which it was immersed, or above that at which it stood in a wider tube, with which it formed an inverted siphon, they were induced to conjecture the possibility of a perpetual motion; for if the water, said they, rises to the height of an inch above that level, let us interrupt its ascent, by making the tube only three quarters of an inch in height: the water will then rise above the orifice, and falling down the sides into the vessel, the same quantity will again rise, and so on in succession. Or, if the water that rises in the capillary branch of a siphon be conveyed, by an inclined tube, into the other branch, a continual circulation of the fluid will take place; and hence a perpetual motion given by nature.

But, unfortunately, this idea was not confirmed by experiment. If the ascent of water, in a capillary tube, be intercepted, by cutting the tube at half the height, for example, to which the water ought to rise, the latter will not rise above the orifice to trickle down the sides. And the case will be the same in the other attempt.

SECTION VI.

On the force of Moisture in raising Burthens.

One of the most singular phænomena in physics, is the force with which the vapour of water, or moisture, penetrates into those bodies which are susceptible of receiving it. If a very considerable burthen be affixed to a dry and well stretched rope, and if the rope be only of such a length as to suffer the burthen to rest on the ground, on moistening the rope, you will see the burthen raised up.

The anecdote respecting the famous obelisk erected by Pope Sixtus V. before St. Peter's at Rome, is well known. The chevalier Fontana, who had undertaken to raise this monument, was, it is said, on the point of failing in his operation, just when the column was about to be placed on its pedestal. It was suspended in the open air, and as the ropes had stretched a little, so that the base of the obelisk could not reach the summit of the pedestal, a Frenchman cried out "Wet the ropes." This advice was followed; and the column, as if of itself, rose to the necessary height, to be placed upright on the pedestal prepared for it.

This story however, though often repeated, is a mere fable. Those who read the description of the manœuvres which Fontana employed to raise his obelisk, will see that he had no need of such assistance. It was much easier to cause his capstans to make a few turns more, than to go in quest of sponges and water to moisten his ropes. But the story is established, and will long be repeated in France, because it relates to a Frenchman.

However, the following is another instance of the power of moisture, in overcoming the greatest resistances: it is the method by which millstones are produced. When a mass of this stone has been found sufficiently large, it is cut into the form of a cylinder, several feet in height; and the question then is, how to cut it into horizontal pieces, to make as many millstones. For this purpose, cir-

cular and horizontal indentations are cut out quite around it, and at proper distances, according to the thickness to be given to the millstones. Wedges of willow, dried in an oven, are then driven into the indentations, by means of a mallet. When the wedges have sunk to a proper depth, they are moistened, or exposed to the humidity of the night, and next morning the different pieces are found separated from each other. Such is the process which, according to M. de Mairan, is employed in different places for making millstones.

By what mechanism is this effect produced? This question has been proposed by M. de Mairan; but in our opinion, the answer which he gives to it is very unsatisfactory. It appears to us to be the effect of the attraction by which the water is made to rise in the exceedingly narrow capillary tubes with which the wood is filled Let us suppose the diameter of one of these tubes to be only the hundredth part of a line; let us suppose also, that the inclination of the sides is one second, and that the force with which the water tends to introduce itself into the tube, is the fourth part of a grain: this force, so very small, will tend to separate the flexible sides to the tube, with a force of about 50,000 grains; which make about $8\frac{3}{4}$ pounds. In the length of an inch let there be only 50 of these tubes, which gives 2500 in a square inch, and the result will be an effort of 21875 pounds. As the head of a wedge, of the kind abovementioned, may contain four or five square inches, the force it exerts will be equal to about 90 or 100 thousand pounds; and if we suppose 10 of these wedges in the whole circumference of the cylinder, intended to form millstones, they will exercise together an effort of 900 thousand or a million of pounds. It needs, therefore, excite no surprise that they should separate those blocks into the intervals between which they are introduced.

[*Hutton. Montucla's Ozanam.*

END OF VOL. III.

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